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WHY WATER METERS NEED TO BE HEAT RESISTANT

By George Read

(Meter and Service Superintendent, Department of Water and Power, Los Angeles, Calif.)

Practically all water meter pistons are made of hard rubber, because this material does not corrode and disintegrate in cold water. It is light, very durable, and somewhat viscous; it does not swell in cold water, hence its displacement remains practically the same, which is essential. It is lubricated by water, but when subjected to heat it will soften, swell and warp.

Experiments made in our laboratories show that these hard rubber meter pistons will swell and slightly warp when subjected to a temperature of 146 degrees Fahrenheit for about fifteen minutes.

Technological Paper No. 216 of the Bureau of Standards, page 622, states that pure hard rubber softens perceptibly at 150 degrees F. and that the operating temperature of a piston of this material in a cold water meter must be considerably below 150 degrees F., particularly since the piston is subject to a very considerable stress. It also states that from experience good practice requires hard rubber pistons in cold water meters not to be subjected to a temperature greater than 100 degrees F.

Experiments made by a maker of special and standard water meter pistons, show that a noticeable expansion will occur on various grades of hard rubber pistons from 120 to 125 degrees F., and between

140 and 150 degrees the piston is liable to stick. The material becomes very pliable at about 200 degrees F.

HOT WATER SYSTEMS

Due to the cold water supply pressure being the means of forcing the hot water where needed, it is directly connected to the hot water storage tank, or the heater coil for an instantaneous system.

The cold water pipe enters the top of a storage tank and extends downward inside of the tank to within about six inches from the bottom, where it discharges. After the heating flame is ignited, the water becoming hot, rises to the top of the tank.

There are two ways of controlling the gas to the heater flame, where storage tanks are provided. One control is by thermostat and the other manually operated. If the thermostat control mechanism fails, or the manually operated control is neglected, the expansion of the water due to heating, and the pressure produced by generation of steam, forces the cold water back toward the water main. This allows the hot water and steam to pass by and damages the meter piston.

The controlling of the gas for the heater flame on an instantaneous heater is by means of a valve operated by the cold water pressure, which is connected to the heater coil. The opening of the hot water faucet causes this valve to turn on a large flow of gas, which is ignited by the pilot flame. If this flow of gas is not shut off by closing the hot water faucet, expansion and steam generated in the coil quickly forces the cold water back towards the meter.

In making 2,276 field inspections for meters damaged by heat, the Los Angeles Bureau of Water Works and Supply found that 75 percent of the heating systems were manually operated, 11 percent were controlled by thermostat, 1 percent were instantaneous and 13 percent were a combination of types.

The trend today for hot water systems seems to be toward a storage tank and heater in one unit, with thermostatic control. The thermostat is placed near the bottom of the tank. When the temperature of the water at the thermostat reaches about 150 degrees F., the thermostat closes the gas cock, leaving only the pilot flame burning. By this method, if the thermostat is working properly, a full tank of hot water is maintained at all times for instant use.

METER PISTONS DAMAGED BY HOT WATER

During the last nine years there were 47,084 meters removed from service due to being damaged by hot water. This is 42 percent of the total number of meters removed because of failure to operate.

From July 1, 1932 to June 30, 1933, there were 4,337 meters removed from service damaged by hot water and the cost for changing, repairing, testing, etc. of these meters amounted to $14,500, an average of $3.34 per meter. From the average cost per meter it can readily be seen that most of those were small residential meters.

When the water is shut off for removing a non-operating water meter, the following notice is either given to the occupant or left on the premises:

"Notice of Change of Water Meter

The water meter attached to your service connection supplying No. ——— has been removed on account of failure to register properly and another one has been installed."

DAMAGED METER REPORT

When the meter is taken apart at the meter shop and is found to have been damaged by hot water, a Damaged Meter Report is filled out. The labor charge for changing and repairing the meter, the cost of the repair parts, transportation, etc., are noted. An additional charge of 40 percent of the labor cost covering administration, engineering supervision, small tools, etc., and 6 percent of material cost to cover warehouse handling, are added to the amount. This report also shows the size, kind and number of the old meter removed; the size, kind and number of the new meter set in its place.

This report is then forwarded to an inspector, who visits the premises and notes on the report the make of heater, the storage capacity or instantaneous, controlled by thermostat or manually operated, in good working order, recently repaired or a new heater, heater was left burning too long, hot water was drawn from cold water faucet, old or new tenant, and any other information that he can ascertain.

As this trouble is not understood by some consumers, the inspector's contact helps to avoid a similar occurrence and paves the way for the collection of the bill.

Where a single pipe from the main to the curb is supplying two service connections, and both are equipped with meters, when one of

these meters is removed from service due to being damaged by hot water, the other, although operating, is taken to the shop for inspection.

The inspection of the second meter, although operative, is necessary, because where two meters at the curb are supplied by a single pipe from the water main, hot water backing through one meter can be drawn through the other.

If no inspection was made of the second meter, the damage by hot water might not be discovered until a later date and the cost for repairing might be charged to the wrong person. Also the meter might have been under-registering for the time since it was slightly damaged. Where both meters serving in this manner are damaged by hot water it is difficult at times to determine who is responsible. In fact, it is so difficult at times that no billing is attempted.

When the report is returned from the field, the information is scrutinized, the damaged parts inspected and meter number checked, and the report filed for future reference. A regular "Bill Collectible" is then made showing the size, kind and number of the meter repaired, the service connection number from which it was removed, the house number and the total charge for damages. Accompanying the bill the Department mails the following notice:

"WATCH YOUR WATER HEATER

Forty percent of all water meters replaced for cause are removed on account of defective hot water systems.

A part of the operating mechanism in the water meter which serves you is made of vulcanized rubber. Whenever your hot water system becomes overheated, hot water or steam will be forced into your service connection and your water meter in turn will be damaged, necessitating repairs for which we must make a charge. In addition to this expense the needless overheating of your water system wastes fuel.

The fuel used by your hot water system is controlled by three common methods; thermostat in connection with storage tank, an automatic valve on hot water supply, and hand or manually operated. When in proper working order either of the first two methods will give satisfactory results and the third or manually operated method is dependent entirely upon the judgment of an individual for turning off. If there is any cause for doubt as to the proper operation of your hot water system we suggest that you consult your plumber. This may save you needless expense and trouble.

In the City Ordinance governing water rates, it is stated:

"The Department reserves the right to attach a meter to any service pipe at any time it shall deem it expedient to do so, and thereafter charge meter

rates. After said meter is so attached any damage to such meter resulting from carelessness or neglect of the owner or tenant, as well as any damage to said meter which may result from hot water or steam from boiler or otherwise, shall be paid by the consumer or owner of the premises to said Department on presentation of bills, and in case such bill is not paid the water may be shut off on said premises without further notice and not turned on until all charges are paid."

The inspecting, explaining, billing and collecting for this trouble is one of the most annoying problems. This takes considerable time, and creates controversy and ill feeling among many consumers. Where change of ownership or tenancy has occurred and the meter did not stop operating at the time it was damaged, it is difficult to determine to whom the damage should be charged. The Department's policy is to be fair and where there is any doubt the consumer is given the benefit.

A feature of this trouble is that there are many meters in service that were not damaged sufficiently to stop their operation when damaged. Such damage is not discovered until a later date. Consequently such meters have lost their sensitivity and in most cases are under-registering.

If we should take into consideration the time in explaining, the expense of inspecting, correspondence, billing, collecting, and loss of revenue through warped or swelled pistons in service that were not sufficiently damaged to stop their operation at the time of damage, our present charges on damaged meters are insufficient.

All meter manufacturing companies realize the trouble and expense that occurs through meter pistons being damaged by hot water, and they have conducted research for some time to produce a piston that will withstand a much higher temperature.

The first testing by this Department of a meter piston, which was supposed to withstand heat, occurred about ten years ago. The results of such testing at that time did not warrant their use.

Since then we have carried on considerable testing along this line, and at this date we have five different makes of special pistons under a durability test and in actual service. The results of testing two such pistons of each make, one at 212 and the other at 280 degrees F. are as follows:

No. 1 Make

First Piston at 212 degrees F. for one hour. There was no change in registration, but disk ball loosened.

Second Piston at 280 degrees F. for one-half hour. Lost 7 percent of full flow and required a flow of 0.83 cubic foot per minute before would operate and then only recorded 70 percent on such flow. The disk balls became loose.

No. 2 Make

First Piston at 212 degrees F. for one hour. There was practically no change in registration, but disk balls became loosened.

Second Piston at 280 degrees F. for one-half hour. Practically no change in registration on full flow, but required a flow of 0.5 of a cubic foot per minute before it would operate and then only recorded 87 percent of such a flow. The disk balls became loosened.

No. 3 Make

First Piston at 212 degrees F. for one hour. There was practically no change in registration.

Second Piston at 280 degrees F. for one-half hour. Lost 2 percent on full flow and required a flow at 0.14 cubic foot per minute before it would operate and then only recorded 70 percent of such flow.

No. 4 Make

First Piston at 212 degrees F. for one hour. On full flow there was practically no change in registration, but lost 3 percent on a flow at 0.16 cubic foot per minute.

Second Piston at 280 degrees F. for one-half hour. Lost 5 percent on full flow and 2 percent on a flow at 0.16 of a cubic foot per minute.

No. 5 Make

First Piston at 212 degree F. for one hour. There was practially no change in registration.

Second Piston at 280 degrees F. for one-half hour. There was practically no change in registration.

NOTE: Apparently *No. 5 Make* is 100 percent efficient up to 280 degrees F., but as this piston is of carbon and is very brittle we have very little faith in it becoming a success. However, experiments are being conducted to overcome this brittleness by finding a binder that will increase its strength.

No. 3 Make has been removed from the durability test because it expands and sticks in the measuring chamber. Experiments are being made to overcome this fault.

In making these tests, the water under the main pressure was heated in a cylinder about 36-inches long and 6-inches in diameter, containing about 4.4 gallons. This cylinder was set vertically and ¾-inch pipe entered the top of the cylinder and extended down inside of the cylinder to within about 6-inches from its bottom. A pet cock was inserted in the top of the cylinder head to allow the compressed air under the top of the cylinder head to escape.

The thermometer was set about 6½-feet and the meter about 7-feet from the cylinder, and due to expansion of the water by heating, together with the pressure produced by the generation of steam, the hot water in the cylinder was forced out through the ¾-inch pipe to the meter towards the water main.

The water main pressure at the location of testing was 35 to 40 pounds per square inch. About 280 degrees F. was as high a temperature as could be maintained for about 30 minutes, due to the small volume of water contained within the cylinder.

TABLE 1

POUNDS PER SQUARE INCH	TEMPERATURE OF STEAM, DEGREES F.
1	215
25	266
30	274
50	297
75	320
80	323
100	338

About fifteen minutes after the thermometer registered 280 degrees F., the water in the pipe was hot for about 135 feet from the cylinder towards the water main. The hot water then was discharged back through the meter by pressure from the main, subjecting the meter piston to abnormal use.

In testing the above pistons at 212 degree F. the meters were connected to a cold water line and set in a vessel containing cold water exposed to the atmosphere. The water was then gradually heated to boiling and the meters were allowed to remain in this boiling water for one hour. The cold water pressure was then used to operate the piston and discharge the hot water out of the meters.

Water pressures in Los Angeles range from about 25 pounds to

considerably in excess of 100 pounds per square inch in some locations. As meter pistons are damaged under these pressures table 1 shows the temperatures that must be produced by over-heating before steam can be generated.

From table 1 it can readily be seen what temperature a piston must withstand without swelling or warping. Whether or not a piston will be made to withstand these high temperatures and still have all the other necessary features that are embodied in the present day hard rubber piston, it is impossible to state. It is quite certain that one will be made that shall withstand a much higher temperature.

A piston that will withstand these high temperatures and be equal in other respects to the present day hard rubber piston means more revenue, less maintenance cost and far better public relations.

CHECK VALVE

Considerable thought has been given to the installation of a check valve to prevent hot water from backing up to the meter without realizing that by so doing a closed system of piping is created, which is dangerous to the plumbing.

According to information appearing in a circular covering a gravity type relief valve, water in a closed system at a temperature of 72 degrees F. with a water pressure of 60 pounds per square inch increases to 265 pounds per square inch when its temperature is increased to 110 degrees F. Another test shows that water in a closed system at 68 degrees F. under a water pressure of 20 pounds per square inch, increased to 200 pounds per square inch shortly after a temperature of 126 degrees F. was reached. These figures are supposedly correct. Marks' Mechanical Engineers Hand Book states, however, that one cubic foot of water at 35 degrees F. which is close to its greatest density expands to 1.017 cubic feet when its temperature is increased to 140 degrees F.

As water is practically non-compressible, according to these figures a tank containing 10 cubic feet of water in a closed system with its temperature increased from 35 to 140 degrees F., to relieve all the pressure due to expansion, 1.275 gallons of water would have to be released.

It is estimated that 2.5 percent of the contents of a tank is necessary to be discharged to prevent further increase of pressure in a closed system when heating from 60 to 160 degrees Fahrenheit.

Due to a check valve creating a closed system and that standard range boilers are guaranteed to be tight up to 85 pounds working pressure and extra heavy boilers up to 150 pounds per square inch when new, it is absolutely necessary that a relief valve be placed in conjunction with a check valve. In order to prevent a relief valve from leaking it is necessary that it be set to discharge at a pressure considerably higher than the static head. A relief valve set to discharge at a certain pressure may require more pressure to open due to corrosion, than it was originally set to withstand.

No doubt there are storage tanks in service whose ultimate strength is not greatly in excess of the force due to water pressure conditions. Consequently such tanks may not withstand the pressure set to govern the relief valve. After a relief valve has been set there is no assurance that its setting will not be tampered with. There are known cases where the water released from a relief valve was considered as a leak, and stopped by plugging.

PRESSURE REDUCING VALVE

Due to excessive water pressure in some localities in Los Angeles it is necessary that pressure reducing valves be installed. As a pressure reducing valve creates a closed system of plumbing, a reliable type of a pressure relief valve must be installed in conjunction with the pressure reducing valve. This guards against failure of the reducing valve or pressure increase, due to expansion or stream generation from the heating system.

WATER METER PROTECTION VALVE

Water Meter Protection Valves, placed between the meter and the heater, are equipped with fusible metal plugs. The valve disk is held on its seat by a screw stem, the lower end of which presses against the fusible metal plug. When the temperature of the water is above the fusing point of this plug, it softens and allows the water pressure to lift the valve disk off its seat. The hot water is released to the atmosphere through the valve opening, and as soon as the heater pressure drops below the inflow pressure, the cold water from the main flows in and discharges through the valve into the atmosphere. The cold water solidifies the softened plug.

Quite thorough tests of two types of these valves have been made. The meter protection valves were set six feet, the thermometer 6.5-feet, and the center of the meter 7-feet from the heater.

Type 1

The fusible plugs submitted with the first type of valve softened at about 189 degrees F., and allowed steaming hot water to discharge into the atmosphere. When the discharge occurred, the water in the pipe was hot about 2-feet beyond the meter. Approximately 10-seconds after the discharge occurred, the meter was at normal temperature. After completion of several of these tests, the meter was found to be undamaged.

Type 2

The fusible plugs submitted with the second type valve softened at about 200 degrees F. and allowed steaming hot water to discharge the same as in Type 1. When the discharge occurred, the water in the pipe was hot about three feet beyond the meter, and about 12-seconds after the discharge occurred the meter was at normal temperature again. After completion of several of these tests this meter was found to be undamaged.

In testing these valves it was found that when the valve stem is screwed down on the fusible plug, due to the pressure on same to seat the valve disk water tight, the valve stem gradually imbeds itself in the fusible metal plug, which relieves the tension on the valve disk and allows the water pressure to lift it off its seat sufficiently to cause a leak.

Twenty-four-hour tests were made for these failures under cold water pressures of 250, 150, 75, and 40 pounds per square inch. Failure due to pressure was noted in each case.

If this valve should be perfected the following must be determined, viz: at whose order and expense would it be set; at what location between the meter and the building should it be installed; who will inspect them from time to time; where will the water be discharged; who will shut off the water when discharge occurs; and who will renew the fusible plug.

The valve permits an open system which eliminates the danger of a tank exploding. In an open system the pressure in the storage tank cannot become higher than the water main pressure.

An open system does not prevent high water temperatures occurring before steam is generated. Temperature increase of the boiling point varies directly as the pressure (see table 1). According to our testing, this valve will prevent the meter piston from being damaged

by high temperatures. If a satisfactory heat-proof piston cannot be made, and this valve can be perfected, it should be used to protect the meter against high temperatures as it permits an open system. Due to the cold water supply being directly connected to the heating system in order to convey the hot water where needed, the installation and maintenance of such a valve should be borne by the consumer.

Cold water meters were not made to measure hot water or steam nor are service connections installed to distribute hot water in a building. The service connection is laid to supply the premises with cold water and the meter is set to measure the water used. Until a heat proof piston or some sort of a meter protection valve is perfected all bills rendered for damages to meters from hot water or steam emanating from the premises should be collected.

(*Presented before the California Section meeting, October 22, 1933.*)

HIGH LIFT PUMPING PLANT AT GRAND CANYON, ARIZONA

By George L. Davenport, Jr.

(*Assistant Engineer, Atcheson, Topeka and Santa Fe Railway, Los Angeles, Calif.*)

A little more than a year ago the Santa Fe Railway constructed at Grand Canyon, Arizona, a pumping plant which has one of the highest lifts of any in this country.

Water, which issues from springs in the sandstone on a plateau 1200 feet above the Colorado River, is collected in a concrete reservoir and from there is pumped up the sheer cliffs to the south rim of the greatest canyon in the world, a vertical lift of 3200 feet.

For many years the railroad had hauled to Grand Canyon an average of 70,000 gallons of water per day from Flagstaff and other points a hundred miles or more away. To eliminate this very costly train haul it was decided, after fifteen years of study and discussion, to raise water from the Indian Garden springs which tourists locate by the patch of bright green in the desert brown of the canyon floor.

The main pumping plant consists of four vertical centrifugal pumps of the turbine type, each of seventeen stages These are arranged in two pairs with the two pumps of each pair in series, so that the effect is that of two thirty-four stage pumps.

Direct connected vertical motors of 60 HP. and 3600 R.P.M. speed drive each pump, and electricity is transmitted to the motors through an underground armored cable which parallels the pipe line down the canyon wall and which connects with the diesel engine generators in the rim power house.

Each pump set can deliver 85 gallons per minute at a pressure of 1470 pounds per square inch, and uses nearly 120 H.P.

Several unique features were involved in the construction of this pumping system.

In order to get materials on the ground for the pipe line, reservoir and pumping equipment a complete set of four cableways located end to end, with spans varying from 600 to 2500 feet, had to be built and finally removed. A total of 1500 tons of materials was lowered over the cliffs by this means, while maximum single loads of five tons were

handled. In addition the cableways were used for the transportation of workmen.

Ten months were required for the entire construction, part of which took place during a severe winter with temperatures often below zero. In spite of extremely dangerous working conditions there were no fatalities and no serious accidents.

The 6-inch pipe line was made of galvanized seamless tubing in 30 foot lengths and was joined together with flexible couplings which had rubber gaskets and were designed to stand a working pressure of 1500 pounds per square inch. All pipe bends were made cold in the field so that there were no fittings on the entire high pressure line. The upper part of the pipe line was made of 60,000 pound steel, but the lower part was made of 95,000 pound steel to resist the high pressure without excessive weight.

In spite of the many cliffs in the canyon wall, ranging up to over 200 feet in height, only 8 percent of the pipe line is actually exposed, and much of the exposed portion is protected from falling rocks by a heavy steel shield bolted to the pipe.

Of particular interest is the method of control of the pumps.

No operator is employed at the pump house, as the starting or stopping of motors or the opening and closing of valves are all accomplished automatically by electric coded impulse control through a second underground cable from the transmitting station in the power house. Water hammer is eliminated by means of automatic hydraulic valves with electric control, combined with a surge suppressor and a slow closing check valve. A weekly inspection has been found ample to guarantee successful operation of the plant.

On the rim the water passes through a duplicate unit zeolite softener and is given a chlorine treatment before it reaches the storage tanks.

During the past year about thirty million gallons have been pumped without any serious interruption of the operation. A retest of the pumps after a year's operation showed no appreciable decrease in efficiency.

As far as can now be seen the extremely high lift is well taken care of by the centrifugal pump installation, and barring accidents from falling masses of rock, which may be expected from time to time along the canyon walls, the operation of the plant appears to warrant belief in its suitability for the unusual conditions which it was designed to meet.

(*Presented before the California Section meeting, October 27, 1933.*)

SELECTION OF EQUIPMENT FOR ELECTRICALLY-DRIVEN PUMPING STATIONS

By S. M. Dunn

(*Assistant Mechanical Engineer, Department of Water and Power, Los Angeles, Calif.*)

Throughout the preparation of this paper the writer has found himself inclined to envy an imaginary water-works engineer of the last generation who might have been called upon to prepare a paper on the same, or a similar subject. In those days the very simple and reliable centrifugal pump was only a newcomer into the water-works field and cheap electric power was unknown. But the much more diversified, and consequently more interesting, steam pump had reached its peak of development and, owing to this diversity of design of both major and minor equipment, a great deal more of informative and interesting material must have been available. In fact, an account of the sometimes weird apparatus in use in those days seems to the writer to make an account of the standardized equipment of to-day seem rather tame in comparison. However, it is hoped that too much of the following material may not too readily be classified as a mere attempt to reveal the obvious.

In these regions, where cheap electric power is so commonly available, the advent of the centrifugal pump has reduced the pumping station of ordinary capacity to rather small and simple proportions. In the layout of a new station of this size the problems to be solved, as far as major equipment is concerned, center principally around the matter of the selection of the number of units to be installed, and the most suitable capacities of the individual units. In attacking these problems the points most deserving of stress are, naturally, reliability of service and the efficiency—first-cost relation. The former of these is obviously the more important, and it can only be insured by so selecting the number and sizes of units that the failure of any one unit cannot reduce the plant output below the designed capacity.

NUMBER OF UNITS

When, as is usually the case, considerable storage capacity exists on the discharge side of the station, the principal consideration in determining the number of units to be installed is the friction head-loss in the supply and discharge lines. If the friction head-loss is low duplicate units of the size necessary to supply the maximum demand should be installed, and these units should be operated alternately to insure availability. This number of units naturally lends itself most readily to compactness of layout and, where space is an item of importance, the units may be stacked.

On the other hand, if the friction head-loss is relatively high it is believed to be best to install three units, any two of which, operated together, will be of sufficient capacity to supply the maximum demand. This arrangement permits a considerable saving in power loss chargeable to line friction as only one pump need be operated during periods of low demand. At the same time it provides insurance against crippling of the service if one unit fails.

Where, as is sometimes the case, no storage, or very little storage, is available on the discharge side of the station, three units of increasing sizes should be installed, and the sizes should be so selected that the combined capacities of the two smaller units will equal the capacity of the larger unit. In many such instances it is advisable to install an additional unit driven by an internal combustion engine.

PUMP SIZES

Pump sizes naturally depend upon station output and the number of units selected, but unless considerable care is exercised in coördinating pump heads and capacities with the actual conditions of operation very poor operating efficiency may result. The centrifugal pump is a very simple and reliable machine, but it is also a very inflexible one, and its peak of efficiency is often limited to a very narrow range of heads.

In plotting the characteristic curves of centrifugal pumps, manufacturers have, with few exceptions, made a practise of plotting heads, efficiencies, and brake horse-powers as ordinates and outputs as abscissas. This has probably been done for no other good reason than that a measurement of height is rather usually made in a vertical direction. However, as it leads to some confusion in determining the performance of pumps under varying conditions, the writer ventures to suggest that the curves would be more usable if the head and ca-

pacity positions were transposed. In selecting a centrifugal pump to work through a certain range of condition as to head we are naturally interested in the effect of changes in this condition on output, efficiency, and brake horse-power, and if heads rather than outputs were plotted as abscissas it is believed that the curves would prove to be much more convenient in use. Where operating heads vary over a wide range high efficiency over the range is naturally desirable, and it will be found that a replot of the curves by the method suggested will often disclose the fact that a pump with an apparent broad high efficiency range, but a flat head-capacity curve will really show up rather badly.

In writing specifications for centrifugal pumps some minimum limit should be placed on the sizes to be quoted upon for a given output. This may be done by taking account of specific speeds, but this is a rather involved subject, and water-works engineers may save the expenditure of some mental energy by specifying pump sizes on the basis of maximum velocity in the discharge nozzle. This maximum, it is believed, should not exceed 16 feet per second. Pumps with higher discharge velocities will have inordinately large diameter impellers, and consequent high impeller skin friction losses, and the loss through the adjacent valves and fittings will also be high. As an illustration of the latter point tests have shown that the head loss through a standard 6-inch swing check valve is 1 foot at a velocity of 8 feet per second, 3 feet at a velocity of 16 feet per second, and 5 feet at a velocity of 20 feet per second.

PUMP DESIGNS

The actual designs of pumps to be selected naturally depend, to a large extent, on the outputs of the individual units, but, in general, except for very small units, the double-suction type of pump is preferable to the single-suction type, and where space is not a limiting factor all two-stage pumps above 3-inch in size should be tandem units. In all multistage, single casing pumps particular attention should be paid to the design of the means for compensating for end thrust. This latter point is one which often causes trouble in operation. Parts which will require renewal, such as impeller wearing rings and shaft sleeves, should be so designed that they may be removed and replaced without damage to other parts. In some cases it is necessary to split worn shaft sleeves which have been pressed on, and a bent shaft may easily result from this operation.

Where the head per stage is high, sealing rings should be of the labyrinth type with not less than two right angle turns. Pumps with straight sealing rings may be made to show high efficiencies if clearances are held to the minimum, but clearances have the bad habit of increasing with use, and leakage tests made by measuring the back flow through old pumps with bands soldered over the impeller ports have shown that the leakage losses in pumps with straight rings reach values several times as high as in pumps with labyrinth rings even after a fairly short period of operation.

Small and medium capacity pumps may be driven at either four- or two-pole motor speed. For capacities up to 1000 G.P.M. two-pole speeds are entirely practicable, and such pumps show high efficiency. For higher capacities, at two-pole speed, motors are available, but the writer is not aware that such pumps are in general use.

Motors, wherever permissible, should be of the full-voltage starting type, and for small and medium sized units synchronous motors should not be used unless savings in power charges are very definite. Synchronous motors, and their control equipment, are subject to a number of diseases from which the much simpler induction motor is free, and unless properly serviced, may fail when most badly needed.

CHECK VALVES, AIR CHAMBERS, AND RELIEF VALVES

When the centrifugal pump came into the pumping station it promoted the check valve from a device sometimes used with reciprocating pumps for relieving the valves in the discharge deck from pressure during periods of idleness to a very important, and sometimes very troublesome, piece of station apparatus. This is particularly true where electric motor drive is used and, while it is possible to bring the column of water in the discharge line to rest slowly before the motor is tripped off by means of a gate valve, either manually- or automatically-operated, the inevitable unexpected power failure must be guarded against. For this reason some care should be used in the selection of check valves, and where extremely high surge pressures are anticipated, relief valves or air chambers should be installed.

In general, it may be said that the check valve should give a full, clear opening equal in area to its nominal size, should be ruggedly constructed, and should be capable of closing as nearly instantaneously as possible. For small and medium sized installations some makes of swing check valves, either with or without external weight levers, if constructed to withstand internal wear, are usually suitable,

but for larger installations more elaborate valves are often necessary. Some makes of swing check valves seem to be designed with the idea in mind that the velocity of the water stream holds the check valve stationary in the open position. This desirable condition, however, does not exist if the valve is of sufficient size, and such valves soon wear to the point where they become dangerous to use. The disc of a check valve on a high pressure pump need be held off its seat only a very small amount to pass the full capacity of the pump in the reverse direction when the pump is not running, and if the valve sticks in such a position and then closes suddenly, the results are usually disastrous. For this reason the stud and nut means of attachment of the disc should not be used.

During the last few years several hydraulically-operated automatic check valves have appeared on the market, but while some of them operate very satisfactorily under proper conditions, they are rather complicated, and are often inordinately expensive when the cost of the pumping unit itself is considered. Such automatic check valves operated by hydraulic cylinders, and controlled by pilot valves actuated by Pitot tubes, have been found to work very successfully, but in many instances where surge conditions are severe it is necessary to take the operating pressure supply from a source other than the main in which they are installed. This necessity arises from the fact that the valve should begin to close at the time when the velocity of the stream begins to fall, and where conditions are bad the pressure in the line may be too low to move the valve rapidly.

Air chambers located as near as possible to check valves have been found to be very effective in some instances in reducing surges, but in other instances they have been found to have precisely the opposite effect. In all cases, however, they have been found to increase the slamming of swing check valves. The reason for this lies in the fact that they tend to maintain the line pressure at a constant value for a short interval of time after the pump motor is tripped off the line, thus causing a more sudden back flow through the check valve, and making necessary a more sudden closure. Attempts have been made to prevent this valve slamming action without cancelling the cushioning effect of the air chamber by inserting a second check valve in its neck, but these attempts have not been uniformly successful.

Relief valves operate successfully in some cases, but in others they have been known to set up a condition of continuous surging similar to that set up by a hydraulic ram. Of late a new relief valve of the

anticipating, slow-closing type has entered the market, and this valve is said to operate very satisfactorily.

The subject of surges in pump discharge mains presents an almost virgin field for research. Surges in turbine penstocks have been quite thoroughly investigated, but the conditions are different, and the writer would welcome an understandable analysis of the subject of surges in pump discharge lines.

MISCELLANEOUS EQUIPMENT

Very few pieces of auxiliary apparatus are ordinarily required in the ordinary electrically-driven plant, but among those presenting anything of a problem of selection may be mentioned priming devices and flow measuring devices. Where water is lifted by suction some sort of priming device is usually necessary unless foot valves are used. The latter are objectionable because of their high head losses, and because of the danger of bursting pump casings if the discharge check should fail to close. For the ordinary plant the water ejector furnishes the best and simplest means of priming if pressure water will always be available for its operation and for packing seals. In other cases one of several makes of rotary vacuum pump is suitable.

For flow measuring purposes in mains larger than 10-inch the Venturi tube, in conjunction with any of the standard makes of flow meter, is recommended. For smaller sizes down to 6-inch the orifice plate may be used, and for still smaller sizes one of the displacement meters. Orifice plates are open to the objection that they must be tested in a similar pipe line for each particular installation if doubts are not to be entertained as to their accuracy, and means for conducting such tests are not usually available. On the other hand, the Venturi tube is comparatively cheap, and very little doubt need be had as to the accuracy of its indication within 1 or 2 percent.

In some instances pump headers have been built up by welding, but it is not believed that this kind of construction has many advantages over construction by means of flanged fittings, while it has a serious disadvantage in the fact that unless the work is very carefully done the strains set up by the welds may cause misalignment troubles in rotating equipment and leaks in screwed flanges.

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GRAVEL WALL WELLS

By R. R. Schweitzer

(*Engineer, Norfolk, Va.*)

In Engineering News Record of June 8, 1933, an article appeared by O. E. Meinzer, Geologist in Charge, Division of Ground Water, U. S. Geological Survey, Washington, D. C. It shows a trend toward the adoption of gravel wall wells by students of water supplies for municipalities and for those industries which use much greater quantities of water than cities of 20,000, or more, population. Mr. Meinzer, however, made no attempts to differentiate between types or methods and means of construction.

It appears appropriate, therefore, at this time to discuss and disclose the weak, as well as the strong, points of the various types of gravel wall wells, and classify them as to the conditions for which they are suited.

Because gravel wall wells may prove to be of advantage over common sand screen wells, it does not follow that all gravel wells that have been installed are successes. In fact, may of them have proven to be most expensive failures. There are also many partial successes which could be greatly improved upon. This is not at all surprising. As is always the case in pioneering work, a given method of installation cannot prove to be the most advantageous under all conditions. If the same method were attempted in all locations and under all conditions, it was sure to have proved to be a failure, in many instances. Unfortunately, a great many engineers and contractors attempt to use types and construction methods in new locations, simply because they have been successful in former experiences.

Practice in well construction has now been advanced to the point where there is little excuse for failure of a gravel wall well, insofar as construction methods are concerned. In the past five years, more advancement of mechanical construction, methods, etc. has been made than in all previous years. To follow the development of the gravel wall well, it is desirable, to review the various types of gravel wall construction.

TYPES

A gravel wall well to be classed as such for use in relatively fine sand formations, or in formations where the percentage of fines are somewhere near 50 percent of the total, should have, first, a screen of no considerably greater diameter than is large enough to carry the amount of water that is estimated will be developed without serious friction head loss in the well tube itself. In figuring this carrying capacity, it should be remembered that all water does not enter the lower part of the screen, so that usually a much smaller diameter screen can be used, especially at the bottom, than would be at first assumed. Consequently, less money spent for screens of large diameter and relatively that much more spent on the system of development or installation is a wise exchange. The gravel retaining element or screen should be as thin as possible to avoid clogging of that element and yet amply strong to prevent collapse. Consequently, metals of non-corrosive types, should have first consideration. The openings in the screen should be large enough to pass freely all of the sands, if they are uniformly fine, and, at least, all of the fines in a material, if it is mixed sands and gravel.

Generally speaking, the openings in the screen should never be less than $\frac{3}{32}$- to $\frac{1}{8}$-inch for the finest sands, and up to $\frac{1}{4}$-inch for the coarser and mixed materials. If the gravel wall well contractor complains that he cannot prevent the finest water-producing sand from coming into the well with those screen openings, then he should either advise himself as to the better methods of graveling a well, or the engineer should seek another contractor.

The metal screen should be designed to hold the filtering media or introduced gravel only. Otherwise, the gravel will gradually "load up" with sand, and the capacity of the well will be reduced to the same amount as a common sand screen well. For relatively coarse sands and material, requiring only one layer or size of gravel, that is, sands of a size 50 percent of which will be retained on a screen of 1.5 mm., and 90 percent retained on an 0.8 mm. screen, gravel of not less than $\frac{1}{4}$-inch (6.35 mm.) should be used; usually gravel that is retained on a $\frac{3}{16}$-inch mesh and passes through a $\frac{3}{8}$-inch mesh will give ideal results in single layer gravel wall wells in sands of the above description, provided a sufficiently heavy wall of gravel is installed.

For those uniformly fine sands that sometimes constitute the entire water-bearing strata of the well, for example, sand, 50 percent of which will pass a 0.4 mm. screen, and all of it will pass a 1.0 mm.

screen, a double gravel wall is required, and at not so much greater an expense of installation as might be thought. In this instance, a layer of $\frac{1}{4}$- to $\frac{3}{8}$-inch gravel from 2 to 6 inches in thickness is placed next to the screen, and a finer gravel or a real coarse sand with a high uniformity co-efficient, and approximately 2.0 to 3.0 mm. in size, is placed in large quantities between the layer of gravel and the native sands. In this manner, a real filter is constructed under the ground. If the proper metals are used for the screen and casings, the work is properly done, and an adequate amount of the two sizes of filter material is placed, there is no reason why the well should not last the full life of the screen and casing materials used, without dropping in capacity. It is, therefore, urged that no expense be spared to use the best casing and screen materials known.

Where "cast iron," "concrete," "terra cotta," and other thick types of screens are used, the gravel space is still more restricted and the force of the development process much reduced, with the result that still thinner walls of gravel are placed.

The gravel wall in such wells becomes inoperative and the well becomes just a common sand screened well of greatly reduced capacity beyond any hope of repair. With the development of non-corrosive metals for screens in the past few years, there is very little argument to be made for screens of other materials.

CONSTRUCTION METHODS

Bailing-in process

Perhaps the first really successful gravel wall wells were constructed by the bailing-in process. This is done by sinking some kind of pit, either wood, steel, or concrete, to or near the water-bearing stratum. In shallow formations, that is, where the water-bearing formations were from 25 to 75 feet from the surface, this pit construction can be successfully accomplished with manual labor and wood-curbing, in the fashion of a mining shaft.

After this is finished, the crude method is to set a screen or perforated pipe on the formation in the bottom of the pit and bail the material from the inside, with an ordinary well bailer, and, by heavy weighting, the screen will gradually sink through the water-bearing formation, gravel being placed around the screen, in the hope that it will follow the screen down.

In the deeper formations, it requires the sinking of a pit of steel,

usually of much smaller diameter than the handmade pits, by the rotary process, or other means, such as cable tools, or by the California method of mud scow rigs, using stove-pipe casing.

A screen with various, and, sometimes, patented type shoes, cones and other devices on the bottom, is then lowered into the pit, and is bailed down, keeping the annular space between the inner and outer casing filled with suitable gravel during the process, the same as in the hand built pits. Some conditions favor this type of construction. Especially is this true in the comparatively shallow mixed sand and gravel conditions prevailing in some of the glacial deposit areas.

Certain fundamentals, however, limit the bailing method. The screen cannot have too wide a shoe or the screen will hang up in going through extensive formations, as the bailer will not cut out far enough. Small boulders, also, easily prevent the casing from going down. This limits the space between the pit and the screen proper, and compels the use in large capacity wells of relatively large diameter screens, involving greater expense, and many hundreds of thousands of dollars have been lost through the collapse of large diameter screens from caving materials, during or after development. The danger of collapse of screen increases, at least, according to the square of the diameter.

In the bailing process, where the stratum being developed consists of varying layers of material, especially where there are layers of fine sand, layers of clay, and layers of mixed material, the gravel that is fed between the casings will arch over to a much greater extent than is believable to the un-initiated, leaving pockets that require strenuous efforts to remove, and fill with gravel through various development processes. In many instances, this is not possible, with the result that these development methods fail, and the well is either a perpetual sander, or it will collapse through the cavings of large volumes of material.

Where the water-bearing zone is not too deep, and material is generally a uniform mixture of sand and gravel of not over fifty feet in extent, and only one stratum is developed, there is perhaps no more satisfactory or cheaper method than the old bailing method, properly designed and installed.

Combined rotary and development process

The next popular method which is adopted for graveling as well, especially in the deeper formations, is the combined rotary and de-

velopment process. Such deposits are found in the cretaceous formations, the sedimentary formations along the Atlantic Coastal Plain, and the finer and more deeply deposited and unconsolidated formations of the Southwest, the Middle West and California.

There is no limit of depth, as far as the writer knows, to which this process can be carried. The wells recently put in for the Suburban Water Companies of Paris, France, were carried to a depth of 2400 feet, and finished with 15-inch screen. These were drilled with the rotary process, and graveled satisfactorily. It is claimed that these wells were constructed with the heaviest string of well casing ever set, where all the weight was suspended at one time. The entire well was an open hole and all casing set at one time.

A number of water wells in Texas and the Southwest have been drilled and graveled to a depth of over 2,000 feet. Oil wells have been graveled with relatively small quantities of gravel to depths of 3,600 feet. On the Atlantic Coastal Plain, a number of wells, 38 inches in diameter, have been drilled to a depth of 800 feet in extremely fine sands, and very successfully graveled with the latest processes, and caused to produce ten times the yield of common sand screen wells in the same formation and locations.

The common method in graveling a well of this type is to rotate a hole through the surface formations and set a pit casing of 18-, 24-, or 38-inch in diameter. Inside of this, as large a hole as possible is rotated down through the first water-bearing formation, and usually in the 18-inch pit, a 12-inch screen is set, in the 24-inch pit, usually a 16- or 18-inch screen, and in the 38-inch pit, a 24- or 26-inch screen, the annular space being used for a gravel envelope or wall. If other formations are found at greater depths, and it is deemed too risky to carry such a small envelope of gravel, or the formation starts to "crowd", a smaller hole is rotated inside of the screen, and a smaller diameter screen, for instance, a 6-inch in a 12-inch pit, a 12-inch in an 18-inch pit, an 18- in a 26-inch pit, and so on, is carried down.

In other words, the well is constructed in telescope fashion, or a well within a well. Each stratum, or series of strata, is developed independently.

After the gravel is introduced, various systems of agitation and development have been used, the principal one being to pump the well at high capacity, thereby drawing the fine native sands and the drilling mud wall through the gravel envelope, letting more gravel settle down from the surface. An agitator is also used, which con-

sists of a plunger, made of wooden blocks and old belting, which fits fairly close in the screens, and this is drawn up rapidly. The agitator, like a plunger, creates a partial vacuum, and more or less agitates the screen and gravel. This assists in the matter of "shaking down" the gravel, and the finer sands are drawn in, due to the partial vacuum. Under favorable conditions, large quantities of gravel are sometimes introduced in this manner. These conditions become complex, however, and many failures occur, and a great deal of experience is required to make the majority of wells even seemingly successful.

Wash-out plugs or valves in the bottom of the screen are used by some operators. In this case, a smaller pipe is screwed into this inverted check valve during the development, and water from the surface forced down through the smaller pipe out under the bottom of the screen. The water is presumed to rise through the annular space between the screen and the native sands through the introduced gravel, thereby washing out the sand by attrition, and letting the gravel settle. The merits of this system are very questionable in most formations, and it is now practically obsolete.

Some operators have had good success in putting the suction of a vertical turbine pump between plunger, or agitator blocks, and while pumping at high rates, raise the pump up and down through all areas of screen, thereby producing the maximum suction limit and a surging effect on various portions of the well screen. This method is extremely costly, and when necessary to develop a well, can generally be considered to indicate inadequate graveling or failure to remove the mud wall created in drilling.

Considerable attention has been given in some instances to development by steam or air. By surging and blowing back, the sands are disturbed, and then pumped in through the gravel.

Generally speaking, the air process has extremely narrow limitations, and is too costly when used in large capacity wells and in most formations. In isolated instances, when compared with some types of gravel wall wells, air developed wells have made a creditable showing.

All of these methods, however, leave a great deal to chance. There may be "crowding" of muck, clay, or gumbo formations; that is, these materials have a tendency to continue to close in on the casing, shutting off the supply of gravel from above. In these instances, there is no redress except to reline the well with a smaller size screen, placing a thin wall of gravel of finer sizes in between the liner and the

original screen. In this case, the value of the larger well is entirely lost. In other cases, a great deal of the drilling mud wall is left, which at some later date may wash in, leaving a running sand pocket and cause the eventual loss of the well.

California stove-pipe casing

California is unique in having a method of its own for development. This method can perhaps be used in other sections of the country with equal satisfaction, if it is desired. Stove-pipe casing is used with a heavy cast iron or cast steel shoe of sufficient thickness to leave a space of several inches between the casing and the side of the well, and while this is put down, the space is kept filled with gravel, the intention being that when the well is completed, it will be entirely surrounded with a layer of gravel. The casing is then perforated and additional gravel is attempted to be fed from above as the well is developed, by either agitation or pumping, drawing the native fine sands through the gravel.

While satisfactory under certain specific conditions, this method is even more haphazard than the common rotary method and telescope well, because of the fact that any "crowding" gumbo or soft clay formations will very easily follow in and cause either layers of clay and introduced gravel to form an envelope around the casing, or, the gravel will be shut off entirely. Furthermore, it is very hazardous to attempt to perforate wells adequately, scientifically, and accurately underground. This statement will, of course, raise a protest from many drillers who use no other method, and much proof will be offered that they can perforate accurately many feet under the ground, but the writer, after some eleven years of experience in the Southwest with this type of drilling, has still to be shown that this is true in even a general sense.

Casing perforated after it is in place cannot be given as large a percentage of openings as a good screen has, and in fine sand formations the perforation method is wholly impossible of consideration. It cannot be successfully denied that if "sanders" are considered failures, the "mortality" rate of "California" type of stove-pipe casing wells is the highest of any type.

"Pull-back" method

Gravel wall wells are also made by the "pull-back" method, which in isolated districts with definitely known characteristics are quite successful.

These wells are made by either the "rotary," "cable-tool," or "bailing" methods, by sinking a solid casing through the water-bearing formation and then setting a screen of more or less smaller diameter concentrically in this casing and filling the annular space with gravel and "pull-back" the casing. This method is claimed by its proponents to assure a complete gravel wall or envelope around the screen. Theoretically, this is true, but in practice it is not.

In shallow formations, where the outside casing is bailed or driven in, it perhaps is superior to the bailing process, but it has the same limitation as regards after-development. The gravel can, and in many instances does, "arch over" after pumping begins. The layer of gravel or "wall" must be very limited for obvious mechanical reasons, and unless this is augmented by additional gravel during development, fine sands will not be eliminated.

If the rotary process is used, the mud wall must still be effectively removed.

The cable-tool method is so limited in the diameter of casing that can be economically placed, that it is wholly out of the question, except in very small capacity wells.

Under-reaming to larger diameters

The cost of large diameter holes to great depths is necessarily high. To offset this, much success has been had in drilling wells of smaller diameters and casing to the principal water-bearing formation, and then under-reaming to large diameters through the formation. Beyond certain depths and under certain conditions, types of formations, etc., this method has proven to be somewhat less costly than drilling a large diameter all the way. There are a great many factors, however, that enter, and there are a great many conditions where it is easily seen that the cost is not reduced, or the process successful.

In sands that are relatively tight and rather uniformly fine, so that they will not break down easily, it may be impossible to remove the drilling mud satisfactorily through the thick gravel wall in the reamed out formation, by the agitation or pumping process, and the upper cased hole is too small to allow adequate development means to be introduced between the screen and the upper cased part of the well.

The method is also almost limited to the development of one or two principal strata on account of the great danger of caving, and the difficulty of developing several areas through the necessarily restricted space. For example, a well that derives its supply from five

or six fine sand strata, the lower one at, say 600 feet, and the upper at 100 feet, with the others scattered through the intervening space, and all of them about equally productive, the cost and dangers of under-reaming would greatly exceed those of other methods.

The under-reaming process, however, holds the solution to more economic installations in a great many instances. It leaves one to decide between the advantage of a large bore in water-bearing formation, and of the great disadvantages of restricted space between the casings in the long space between the surface of the ground and the screened horizon.

The same objection and reason for not using the rotary and development process, and there is ample reason for these arguments, that it has been impossible to remove the drilling mud wall adequately from considerable of the formations by agitation and pumping, and that the gravel envelope is a matter of guesswork, applies to the under-reaming method as it does to large bore wells.

Experimental methods

In order to overcome these objections, many experiments, especially on the Atlantic Coastal Plain, were made. Much larger holes were bored through all formations before setting any casing or screens, except the surface pit, and smaller diameter screens than had originally been supposed to be efficient were used, with the result that it was found that these wells were far more efficient. The success of installation and permanence were far more secure, in using a 38-inch bore and an 8-inch screen in the lower strata and 10-inch in the upper strata, the wells having from 12 to 15 inches of an envelope of gravel in the bore hole itself, than could possibly be had from any design of "telescope" well, even though the upper stratum of the "telescope" well had 30-inch screen and the lower stratum 12 to 18-inch screen.

Desirable objectives

Having pointed out the various points in graveling methods, it is well to list specifically the desired objectives in building a gravel wall well, as follows:

(1) Keep the cost within reason.
(2) Install an adequately thick wall, or envelope, of the proper size gravel to form a continuous and perfect filtering medium.
(3) To remove positively all the drilling mud wall and as much native material as possible from the water-bearing horizons.

(4) To replace such excavations immediately with the filter gravel to avoid cave-ins.

To accomplish these results, it requires:

(1) A strong hydraulic mining action on the drilling mud walls of the well and the native sands.
(2) The immediate removal of such mud and sands.
(3) The definite and positive placement of the filter gravels at the point and at the time of the hydraulic excavation of the sands.

To do this successfully, it is obvious that the well bore must be large enough to admit adequate mechanical washing devices between the screen and the drilling mud wall.

RECENT DEVELOPMENTS

The writer, over a period of years, has attempted to reach these objectives with increased success at each trial. The first was made with slotted 2-inch wash line pipes, placed between the screen and the mud wall, washing out the muds and sands from their places, letting the return water carry the sands and mud to the surfaces, and feeding gravel from the surface in the annular space between the screen and the well bore. While this first step was a great improvement over the agitating and pumping methods, difficulty was had in getting a definite force of wash water against the drilling mud walls and bringing the sands to the surface.

Later experiments involved the use of special nozzles, with upward and outward jets, attached to the ends of three or more pipes placed in the annular space, using wash water under high pressure. This experiment brought better results than the former, but difficulty was encountered in keeping the nozzles positively spaced. The gravel in this instance, also, was merely dumped in at the surface and allowed to settle down through the rising mud water and sand. This seriously interferes with both the settling of the gravel and the elimination of the sand. The entire operation did not yet remove the chance of incomplete elimination of the drilling mud wall.

Circular nozzle device

The latest specifications have completely removed this chance, and call for a circular nozzle device placed around the screen in the annular space between the screen and the mud wall to which are attached two, or more, pipes extending to the surface. These pipes,

three inches or more in diameter, serve the dual purpose of supports for operating the device, by raising and lowering and conveying the development water and filter gravels to the exact desired point. The device being intermittently raised as the well is developed and graveled from the bottom upward and removed when the well is completely graveled.

In the outer periphery of the device are upwardly and outwardly pointed nozzles of $\frac{3}{4}$-inch diameter, spaced about six inches apart, the nozzles being properly shaped to give the water the most concentrated hydraulic force. This circular device is of a diameter just smaller than the bore of the well, so that the nozzles are at the most but two or three inches from the drilling mud wall.

In operation, water under adequately high pressure for the formation being developed is forced down one of the supporting pipes and out the nozzles, creating a hydraulic mining effect, with any desired force, directly against the mud walls and native sands.

Down the second pipe, which has an opening just above the nozzles, water and the filter gravel are pumped. This gravel is, therefore, carried by the nozzle streams against the muds and sands, and owing to the gravels higher gravital tendency remains in the place formerly occupied by the native sands, the native sands and muds being floated upward in the well bore in the same manner as in the drilling process, but much more rapidly, on account of a much greater amount of water.

A third pipe with open end is placed at a short distance above the device, depending on local conditions, size of sands and gravel, etc. This is the suction of a self-priming dredge type pump placed at the surface of the ground, and the native sands and muds which are lighter than the filter gravel are pumped off through this pipe and pump, removing the necessity of their being floated out the entire distance of the well depth.

In the old method, the sand was supposed to rise with the mud under a very low velocity head, and contrary to this, the gravel fell, through the rising sand. With the present method, the water and gravel are carried down under great velocity, and the rising sands ascend through a rising pipe under high velocity.

This method very definitely accomplishes all of the objectives outlined above for the ideal gravel wall well. The cost is reasonable, especially when the additional capacity and the life of the well are considered. The gravel wall in fine sands can be made of almost

any thickness desired, it cannot help but be a continuous wall, all the drilling mud wall is certain to be removed, and the gravel is placed at the time and point of excavation.

For double gravel wall wells in fine sands, by extending a false casing of the same size as the inside diameter of the circular device, from the device to the surface, two layers of different size gravel can be placed at a very reasonable increase in cost.

RESULTS

While this method is not always the best to be used, under all conditions, it does have a wider range of application than any other method of making gravel wall wells. The results are the proof of the adequacy of the method.

In wells installed along the Atlantic Coastal Plain, a known diameter (from the amount of sand recovered and gravel placed) of six feet, and more, has been excavated at depths of over 600 feet.

A "telescope" type of rotary gravel wall well at Sumter, South Carolina, developed by the best known means for such wells, produced 700 gallons per minute with a specific yield of 5.3 gallons per foot of drawdown. The improved type of well drilled within 200 feet of the first well, and constructed with the hydraulic mining action described, through the same formations, plus five extremely fine sand strata which were impossible of development with any other known method, produced over 1500 gallons per minute, with a specific yield of 24 gallons per foot of drawdown.

The "telescope" well was always a "sander." The improved type of well never yielded any sand. Over 190 yards of gravel were used in the improved well. The cost of the later well was less than the cost of the "telescope" well.

At West Point, Virginia, a well 590 feet deep, passing through six sand strata (all fine sand) that it was desired to develop, was drilled, and attempts were made to develop by the agitation and pumping method. The well was brought to a production of 568 gallons per minute, and a specific yield of 8 gallons per foot of drawdown. Thirty-five yards of gravel were used, at a cost of 736 man-hours in developing, at which time the well was a complete loss through collapse.

The rig was moved thirty feet and the same size bore, 26-inches, was again made. The hydraulic mining method with the circular device was used in the development, 70 yards of gravel were used,

the production was 1125 gallons per minute, specific yield 16.2 gallons per foot of drawdown, at a cost of 835 man-hours, and the results—a perfect well.

This method, however, has certain features which are objectionable, under certain conditions. It should not be used under conditions that are more or less ideal for bailing installations, as perhaps very little or no better results will be had and the cost will be greater.

The method, while not expensive, if properly handled, does require much more experienced operation and supervision, as it is a complicated matter. It is the outgrowth of experiment, and many details must be given careful attention, or a failure will be made in the installation, either in the results, or the well will be lost. No one inexperienced in the actual practical operation should attempt an installation of this kind without expert supervision, unless he is prepared to sustain numerous and expensive set-backs. Like every other good thing, it has exacted its price from those who have developed it.

SUCCESSFUL PROGRAM IN ELIMINATING CROSS-CONNECTIONS

By J. S. Longwell

Chief Engineer and General Manager, East Bay Municipal Utility District, Oakland, Calif.)

This paper outlines the program followed in eliminating cross-connections between the distribution system of the East Bay Municipal Utility District and various private sources of supply.

In considering this subject the term cross-connection is defined as a physical connection between the carefully controlled potable public water supply and any private water supply, through which water from the private supply may flow into the public system by the opening of gate valves which separate the two systems, or by leakage through gate or check valves of inadequate design or improperly maintained.

The territory served by this District includes the cities of Oakland, Berkeley, Richmond, Alameda, Piedmont, San Leandro, El Cerrito, Albany and Emeryville, together with a large amount of adjoining unincorporated territory in Alameda and Contra Costa Counties, all located on the easterly shore of San Francisco Bay and having a total population of approximately 500,000.

In the early development of the East Bay area, the building was largely confined to the lower lands adjoining the bay. Here a comparatively good supply of water was found at reasonable depths and many wells were put down for domestic and general use. As the community grew and water supply systems were constructed, services were installed for many consumers to supplement their well supply. Industries and commercial houses also took advantage of the ground water supply and installed wells. Likewise most of these concerns supplemented their private supplies with connections to the public distributing system. Industries along the water front in some cases equipped their plants with salt water systems, pumping water from the bay for fire protection and cooling purposes. These also in most cases were connected to the public supply.

These private systems were separated from the public system by gate valves or check valves, which were operated to meet the conditions of the various consumers. No special supervision was given to these connections and as long as the private supply was bacterially safe no troubles resulted. However, instances occurred where the gate valves were not closed or leakage occurred through the valves and bay water or well water was pumped into the public mains causing in come cases very serious conditions. Numerous cases have also been found where private supplies have entered the public mains when the pressure was low for various reasons. Examinations of many of these cases have shown the private supply to be of very questionable character and, although individual analysis may show the water to be safe, conditions surrounding the wells are such that pollution may easily take place unless strict supervision and control is exercised.

For many years it had been appreciated that these cross connections were a source of danger to the community and from time to time efforts were made to have the consumers take steps to eliminate the hazard. Only indifferent success resulted from these programs due largely to the fact that the management of the public supply was without proper authority to force eliminations and it was therefore necessarily a matter of the individual consumer realizing the danger and taking the necessary steps to prevent trouble. It may be said, however, that quite a number did comply with the request but at best they represented a small percent of the total number involved.

The distribution system supplying this area was acquired by purchase from the East Bay Water Company in December, 1928, and shortly after the change in ownership, the District, in order to prevent any further increase in the number of cross connections, and realizing the importance of the matter, issued the following regulation:

"Rule 6 (e) Usage of Service Detrimental to Other Consumers.

The District will not furnish water service to apparatus and appliances, the operation of which will be detrimental to the water service being furnished by the District to its other consumers in the immediate vicinity or supplied from the same distribution system, and the District will refuse to continue furnishing water to any consumer who shall, after being notified by the District to discontinue the use of water for such apparatus or appliances, continue to so use the same, and service will not be resumed until the requirements are met. *No new cross-connections will hereafter be permitted.*"

This regulation was rigidly enforced and studies were carried on as to

the best methods to be followed in eliminating those connections already existing.

Shortly after this procedure was adopted, the District completed its aqueduct system and brought water into the District from the Mokelumne River, to supplement the local sources of supply. At that time application was made to the State Department of Public Health for a permit to deliver this new supply to the consumers of the District. This matter was under discussion when the following order was issued by the United States Treasury Department.

TREASURY DEPARTMENT

BUREAU OF THE PUBLIC HEALTH SERVICE, WASHINGTON

January 11, 1930

To all State Health Officers:

Hereafter water supplies used by interstate carriers for drinking and culinary purposes will not be given a full certification if cross-connections exist between the supply and any other supply; except, when such cross-connection is with another potable supply or a potable supply regularly examined by those in charge of the supply to which cross-connected; and except, further, when such cross-connections are equipped with modern protective devices approved by the State Department of Health and installed and operated under the direct control of that Department. Auxiliary intakes and by-passes are considered as cross-connections.

In making recommendations relative to certification of water supplies used by interstate carriers, you should be guided by the above outlined policy.

Respectfully,

H. S. CUMMING,
Surgeon General.

This was of particular concern to the District as water was furnished to many inter-state carriers and after further conferences with the officers of the State Department of Public Health as to the necessary steps to be taken to obtain the issuance of a permit and the best plan to be followed in eliminating all cross-connections, it was agreed that a temporary permit for the delivery of water would be granted and, in the meantime, the District would proceed with a survey of cross-connections in the system. Upon completion of this survey, a conference of all interested parties would be called and a definite plan agreed upon.

Accordingly, a temporary permit was issued on September 19, 1931, and the District began immediately a preliminary canvass of cross-connections. This was completed early in 1932 and on February 11, 1932, a conference was held in the office of the District in Oakland at

which representatives were present of the State Department of Health, City Health officers, representatives of the nine cities comprising the District, and officers of the District.

The present conditions regarding cross-connections were thoroughly considered and discussed and various plans of procedure were outlined. As a result of the meeting and the plans developed, the State Director of Public Health issued the following order as of March 21, 1932:

STATE OF CALIFORNIA

DEPARTMENT OF PUBLIC HEALTH

Sacramento

March 21, 1932

East Bay Municipal Utility District,
Oakland, California.

Gentlemen:

In the matter of the application of the East Bay Municipal Utility District for permit to supply to the district and small adjacent areas, through the system formerly owned by the East Bay Water Company; also to enlarge San Pablo Filter Plant and Upper San Leandro filter Plant, and to serve Mokelumne River water provided it is safe, physically attractive, and potable, date of application October 18, 1929;

I wish to inform you that the State Board of Public Health, at its regular meeting held on March 12, 1932, adopted the following resolution:

"WHEREAS, there are numerous cross-connections existing between the distribution system of the East Bay Municipal Utility District and private sources of supply in such manner that a flow of water into the distribution system of the East Bay Municipal Utility District is possible therefrom, and

WHEREAS, such private sources of supply are not under sanitary supervision and are of unknown safety and purity, and therefore the cross-connections constitute a menace to the health of the water consumers of the district, and

WHEREAS, the water supply permit to said District, issued by the Board of Public Health on September 19, 1931, is temporary by reason of the above circumstances, until the elimination of the various cross-connections.

Therefore, Be It Resolved, that the following order be issued to the East Bay Municipal Utility District, under the provisions of the Sanitary Water Systems Act and is a part of the aforesaid temporary permit:

The East Bay Municipal Utility District shall:—

1. Make or cause to be made surveys of premises of its consumers and determine whether there is a dual or private source of supply thereon, or any equipment of any kind, class or description which may contain water unfit for human consumption, and determine whether such source of water or equipment is physically connected with the public water supply piping at the East Bay

Municipal Utility District in such a way that a flow of water into its system is possible from such source or equipment.

2. Where private water systems involve the use of tanks the District's supply shall be made to discharge over the top of said tanks.

3. Where private water systems do not involve the use of tanks, the cross-connection shall either be eliminated entirely or protected by a double check valve system to be approved and suitably installed for convenient inspection and test. The installation shall be inspected and tested for its water-tightness at intervals of not more than six months, and reports of findings filed with this Board. The District shall be required by the Board to order out any installation found from these reports to the Board as not reliable in preventing the passage of the private supply into the public system.

4. There shall be no new cross-connections installed between private water systems and the system of the District.

5. The above measures shall be carried out by January 1, 1933."

Yours very truly,

GILES S. PORTER,
Director of Public Health.

CROSS CONNECTION SURVEY

The District then began its program of complying with this order. Every industry, business house and home having a well or other possible source of secondary supply was visited and inspected for a cross-connection. Complete data were obtained on the secondary supply, a sketch was made of the piping showing the connection between the two systems and a sample of water from the secondary source was obtained. Bacterial and part chemical analyses were made of these samples at the District's laboratories and the results were shown on a standard inspection form.

This work was carried on by three inspectors and over 2,000 inspections were made. Out of this number of inspections, 408 active cross-connections were located, which may be divided into the following groups:

Private wells for domestic use	224
Private wells for industrial use	80
Private wells for commercial use	88
Salt water supplies	6
Swimming pools	10
Total	408

In order to standardize all double check valve installations that might be required in carrying out the program, drawings were prepared and approved by the Chief of the Bureau of Sanitary Engineer-

ing of the State Department of Public Health, showing typical installations for the various sizes of services. All drawings specified the use of rubber seated check valves spaced sufficiently far apart to eliminate the possibility of both checks being held open by sticks or other objects which might get into the pipe system. Gate valves were required, adjoining each check valve, to permit inspection and repairs. Complete descriptions were given as to the method of testing the installation for leakage and the necessary gauges and drains were provided to carry out these tests.

As the survey progressed, the cross-connections located, and complete data obtained thereon, the matter of elimination was discussed with the owner of the property and he was presented with a copy of the order from the State Department of Public Health. A plan of complying with this order was worked out and a time set for the completion of the work.

CORRECTIONS

The methods followed by the 408 consumers in carrying out this program, together with the number adopting each of the various methods were as follows:

Service removed—51

The consumer elected to retain his private source and to have the District's service removed.

Two supplies disconnected—183

Both supplies were retained but a complete disconnection was made between the two systems so that they operated independently. This method was used largely by those who desired to use their well for irrigation and industrial purposes and the District's supply for use within the house or plant. By far the larger number of eliminations were accomplished by this method.

Public supply carried over top of tank—68

The consumer arranged to carry the supply from the District over the top of his storage tank. In such cases, the tank was normally supplied by pumping from a well and the District's supply was used to augment the private supply.

Well abandoned—18

In cases where the well was inadequate, either as to quantity or quality, the District's supply was required, the consumer elected to abandon his well and to take his entire supply from the District.

Double check valves installed—88

Many industrial plants, commercial concerns and others had extensive piping systems supplied from wells or from the bay, which were cross-connected to the District's system. Many fire systems were also arranged in a similar manner. In addition, a number of consumers had pressure systems and various types of private supplies which could not be separated from the District's system in any of the four plans outlined above, except at great inconvenience or expense. In all such cases, the use of double-check valve installations was arranged for in accordance with approved plans, and copies of the plans were furnished to the consumer to guide him in making the installation and to insure uniformity, in so far as practicable, for all such installations. In a few instances the consumer had, prior to starting this program, installed double check valves which did not have the specified rubber seats. In case these checks were equipped with bronze seats and in good condition they were allowed to remain, providing the balance of the equipment was in accordance with the plans. This procedure was followed because the change would have required a considerable expenditure and it was considered that proper inspection was of more importance than the rubber seat requirements.

Comparatively little trouble was experienced in obtaining full compliance with the order from the State and the consumers cooperated fully throughout the program. All expense in connection with the required piping changes and the installation of double check valves and miscellaneous fittings and structures was borne by the consumer.

As the program progressed, it was necessary in many cases for the inspectors to visit the consumer a number of times before full compliance with the order was obtained, but considering the general economic conditions existing at the time the work was done, the consumers are entitled to great praise for the rapidity with which they complied.

After each of the consumers had eliminated the existing cross-connection and complied with the State's order, a signed statement

was obtained to that effect. These statements were filed with the report on each cross-connection and indicated the completion of program for each consumer.

A summary of the work accomplished is shown in table 1, giving the number of consumers complying with the elimination order by the various plans, classified as to cities and communities, together with the results of the data collected regarding the quality of the private supplies.

TABLE 1

Complete summary of cross-connection investigation

CITY	NUMBER OF CONNECTIONS	NUMBER SHOWING B. COLI	NUMBER B. COLI IN EXCESS OF 100	CHLORIDES IN EXCESS OF 200 P.P.M.	CLASSIFICATION			METHOD OF ELIMINATION				
					Industrial	Commercial	Domestic	Service out	Disconnected	Over top of tank	Well abandoned	Double checks
Alameda	43	11	8	6	2	11	30	7	18	6	6	6
C. C. County	7	4	1	0	3	0	4	1	4	2	0	0
Ala. County	8				0	0	8	0	8	0	0	0
Berkeley	56	14	2	1	9	18	29	0	24	10	5	17
Emeryville	14	5	2	0	9	2	3	0	7	3	0	4
El Cerrito	21	8	4	3	1	1	19	5	16	0	0	0
Oakland	173	13	3	15	50	46	77	17	72	35	7	42
Piedmont	10	1	0	0	0	1	9	2	3	0	0	5
Richmond	48	13	3	7	11	10	27	8	21	10	0	9
San Leandro	28	7	0	0	3	7	18	11	10	2	0	5
Albany	0	0	0	0	0	0	0	0	0	0	0	0
Totals	408	76	23	32	88	96	224	51	183	68	18	88

Early in December, 1932, or approximately eight months after the date of the State's order, all cross-connections had been eliminated and the program completed. Upon notification from the District of full compliance with the order, representatives of the State made an inspection of the premises where cross-connections had been eliminated and on January 28, 1933, the following resolution was adopted by the State Board of Health:

WHEREAS the State Board of Public Health believes that the East Bay Municipal Utility District has carried out the terms of a certain order made by this Board of March 12, 1932, for the elimination of cross-connections between

its system and private water supplies, which order was issued in pursuance to a Temporary Permit granted to said District on September 19, 1931.

Therefore Be It Resolved, that said Temporary Permit be and is hereby rescinded and in its place full permit is issued in accordance with the Sanitary Water Systems Act, with the understanding that the District will continue to enforce the provisions of the anti-cross-connection order, and that consumers or owners who may violate the provisions thereof shall be required by the District to install suitable approved double check valves or that the District service to such premises shall be discontinued.

REGULAR FOLLOW-UP INSPECTION

With the completion of the elimination program, the semi-annual inspections of all double check valve installations were commenced. During 1933 both inspections have been completed by a representative of the District. All such installations were carefully checked and where any leakage occurred the Owner's attention was called to the matter. The checks were promptly placed in good condition after which a second inspection was made. In the two inspections that have been made the following conditions have been found:

INSPECTION	DOUBLE CHECK VALVE INSTALLATIONS INSPECTED	NUMBER FOUND SHOWING LEAKAGE IN	
		1 check	Both checks
1	88	6	3
2	88	3	0

Practically all of the leaks reported in the checks have been due to rust or other foreign material catching on the rubber seats during the time water is flowing from the public supply. When the pressure from the private supply closes the checks the foreign material is thrust into the rubber and tends to prevent a complete closure, until the material is removed. In the case of metal to metal checks in good condition, similar troubles have not been experienced due, no doubt, to the crushing of the foreign material on the metal checks and seat. Experience, thus far, has been that metal to metal checks, if properly inspected, give the most satisfactory results.

By reference to table 1 it will be noted that by far the larger number of consumers completed the elimination of cross connections by disconnecting the private supply from the public supply but retaining both supplies. Such disconnections present a certain hazard in that the consumer may, upon a break-down in his private supply, reconnect the two piping systems and upon resuming use of the private

supply may fail to disconnect from the public supply. As a safeguard against such practice, inspections are being made of the properties where disconnections have been made and notices are left requiring the notification of the District in case the private supply is shut off. Wherever it is found that the two systems are reconnected, it is planned to require the installation of double check valves or the adoption of one of the methods of elimination which will not permit of a cross-connection.

In conclusion it may be said that the program as outlined has worked out in a most satisfactory manner and it is believed that the District's distribution system is now amply protected against the possibility of cross connections and their related troubles.

(*Presented before the California Section meeting, October 26, 1933.*)

RAILROAD WATER SUPPLIES

By C. R. Knowles

(Superintendent of Water Service, Illinois Central System, Chicago, Ill.)

There are something like seventy thousand locomotives in operation on American railroads. These locomotives ran one billion three hundred forty nine millions miles, hauled twelve hundred fifty billion gross ton miles freight and carried eighty-eight million four hundred thousand passengers in 1926. (The year 1926 is selected for the reason that it more nearly represents normal conditions.) These same locomotives consumed four hundred thirty-two billion gallons of water at more than eighteen thousand water stations throughout the country. These water stations are distributed over more than two hundred sixty thousand miles of railroad, representing every kind of water in every part of the country.

The amount of water used by our railroads exceeds all other materials used, both in volume and weight. The annual consumption of water for all purposes is approximately 620 billion gallons. The annual expense for maintenance and operation of these water stations is nearly $50,000,000.

As stated by a writer in the Scientific American with a taste for statistics, it may help in attempting to form an idea of the immensity of this volume of water if it be reduced to cubic feet and divided by the flow in cubic feet per second of the Amazon River. The result shows that the railroads consume annually a quantity of water equal to the total flow of the greatest river in the world for a period of twenty-four hours, or to apply a standard of comparison nearer home the volume of water used by the railroads is equivalent to the total normal flow of the Mississippi River at its mouth for about forty-eight hours. As another comparison, 20 million cubic feet of water tumbles over the Niagara Falls each minute. If the annual consumption of the railroads were diverted into Niagara River it would run the cataract for about three days.

WATER STATIONS

Water stations are spaced from twenty to thirty miles apart, depending on curvature, gradient and density of traffic, and also to a certain extent upon the availability of a proper water supply. In locating a railroad it is not always possible to select a route where satisfactory water supplies are available, therefore, the railway water supply officer is sometimes compelled to resort to the practice of the pioneers or earlier settlers who camped where wood and water were available.

In the construction of a 200 mile line by a middle western railroad a few years ago the new line was projected through a semi-arid country devoid of natural water supplies with the result that it was necessary to construct impounding reservoirs and pipe water from great distances at some points with the result that the cost for water alone added nearly $500 per mile to the cost of the railroad.

Extreme difficulty is experienced on many Western railroads in securing sufficient water to keep the traffic moving. For example, on the Union Pacific between Bitter Creek and Green River, Wyo., local water supplies are so bad that they are unfit for any purpose. Consequently it is necessary to haul water used for all purposes in tank cars from Green River. The Union Pacific has large coal mines at Rock Springs about fifteen miles east of Green River, and as the water at Rock Springs is unsatisfactory for use the company pumps a supply through an 8-inch main from Green River. The Union Pacific also has a fifteen mile pipe line at Rawlins east of the Continental Divide.

The Santa Fe also finds it necessary to haul water at a number of points in the far West. All of the water used on the Grand Canyon Line from Williams to Grand Canyon, Ariz., is hauled from Leon Springs, a point about twenty miles west of Williams.

The Southern Pacific has a 52 mile pipe line near the western shore of the Great Salt Lake, and a total of 150 miles of pipe line are required between Ogden and the Sierras to supply water for Southern Pacific locomotives.

In most instances water is stored in tanks and delivered to the locomotives direct from the tank by spouts or from water columns which are conveniently located between tracks. Within recent years train delays have assumed a new importance to railroad operating officers and as a result the time lost stopping for water has become a matter of concern in train operation. It is of constantly increasing importance in the operation of both passenger and freight trains. The

shortening of both passenger and fright schedules is constantly becoming more intensive. Throughout the country passenger trains are being speeded up and wherever their time is shortened the elimination of unnecessary stops for water becomes imperative. Heavier freight trains are likewise being operated on faster schedules and also require careful study to control the number of stops made for water.

Some of the Eastern roads have what are termed track pans located between the rails, which permit of taking water without stopping. For example, the New York Central has fourteen of these track pans between New York City and Buffalo and ten from Buffalo to Chicago. From 500,000 to 1,000,000 gallons of water are delivered into locomotive tanks daily from each of these pans. These track pans are about 20 inches wide and from 1400 to 1500 feet long. The depth of the pan is limited for the reason that the proper clearance must be provided between top of pan and brake rigging. The length of the pan is limited to 1400 to 1500 feet because it would be practically impossible to keep longer pans level enough to retain the required amount of water.

The operation of these pans is quite expensive as it is necessary to keep the water warm during the winter months to prevent freezing, a large proportion of the water is wasted in scooping and the maintenance of the scooping equipment is excessive. Therefore, the chief effort toward reducing water stops is through increasing the size of engine tenders. Modern locomotives have tender capacities up to 23,000 gallons, the weight of the water alone in one of these tenders being in excess of the total weight of the engine and train of a hundred years ago.

Long locomotive runs are also a factor affecting the importance of water supply, particularly as to quality. The Illinois Central is running locomotives regularly between Chicago and Sioux City, and Memphis and New Orleans, a distance of over 500 miles. Other roads are running trains from 400 to 900 miles without changing engines. Some time ago the Northern Pacific made a record breaking continuous freight run in which a Mikado type locomotive pulled a train from Seattle, Wash., to St. Paul, Minn., without the locomotives being uncoupled from the train and without receiving any terminal attention enroute. A distance of 1,898 miles over three mountain ranges with maximum grades of 2.2 percent was covered in 109½ hours' total time. The Great Northern ran an engine and train from Seattle to St. Paul and return, a total distance of 3,462 miles a short

time ago, while the Burlington handled a train of 60 cars with 4,650 tons of coal from West Frankfort to Chicago, a distance of 413 miles with a common mountain type locomotive.

All of these developments in locomotive operation call for water supplies of the highest quality in order to keep pace with constantly changing and improved transportation methods.

AMOUNT OF WATER CONSUMED BY LOCOMOTIVES

It is extremely difficult to establish definite figures showing the amount of water consumed by locomotives. This will vary with existing conditions. However, tests show that freight trains consume from 75 to 140 gallons per thousand gross ton miles. The average consumption of water per passenger train mile is 40 to 80 gallons depending on tonnage of train, rate of evaporation, area of heated surface, type of engine and other conditions.

The Flying Scotsman on the London and Northeastern, a 420-ton passenger train, consumes approximately 35 gallons per mile for the non-stop run between London and Edinburgh. The Cornish-Riveria Limited from London to Plymouth, England, a non-stop run of 226 miles with a 450-ton train, uses 40 gallons per mile. The twentieth Century Ltd., between Chicago and New York, an 800-ton train, averages about 80 gallons per mile.

DRINKING WATER REQUIREMENTS

The water used on dining cars and in the coolers of passenger trains represents a comparatively small part of all water used on a railroad yet it must be given even greater care than the water used in locomotives.

Some of our municipal water supplies while acceptable to the communities they serve will not meet the standards established by the Quarantine regulations for drinking water used on Interstate Carriers. These quarantine regulations apply not only to the water itself but to the quality of ice and the manner in which the water and ice is handled. Each carrier must obtain a certificate of purity for each and every supply used on passenger trains twice a year.

BOILER TROUBLES

The principal boiler troubles due to the use of bad water are scale formation, corrosion of tubes and sheets, and foaming. While they are all serious problems and justify investigation and treatment for

their control in any boiler they are particularly troublesome in locomotives.

The presence of scale in boilers obstructs the passage of heat from the flue to the boiler, thereby necessitating higher temperatures in the firebox and more fuel for a given production of steam.

Pitting, either chemical or electrolytic, destroys the flues or the boiler sheets which it attacks.

Foaming of the boiler causes low steam pressure and reduced hauling power and also destroys lubrication in engine cylinders.

The complete lime and soda treatment followed by sedimentation and filtration is generally accepted as the most efficient and satisfactory form of water treatment for locomotives. Briefly, this process consists of adding lime and soda ash in proper quantities to the water, converting the impurities into insoluble precipitates and removing them from the water either by sedimentation or filtration.

Interior treatment, or the use of boiler compounds, soda ash or other chemicals, is in all probability as old as the boilers themselves. Almost every conceivable substance has been used in internal treatment of boiler feed waters, including potatoes, starch, sugar, molasses, tan bark, and boiler compounds of all kinds.

About seventy-five billion gallons of water are treated completely with lime and soda ash at some fifteen hundred of the water stations. In addition to the water completely treated nearly one hundred million gallons are treated by chemicals and compounds applied either to the roadside tank, locomotive tenders or direct to the boilers.

CONDITIONS IN IOWA

There are about five hundred railway water stations within the State of Iowa, serving nearly ten thousand miles of railroad and supplying fifteen billion gallons of water per year.

As an indication of the character of Iowa waters as used on railroads five billion two hundred million gallons of water are completely treated at ninety-eight of these water stations.

The cost of treating will average seven and one-half cents per thousand, or a total cost for complete water treatment on all railroads in Iowa of $400,000 per year. Various forms of internal treatment are followed with many of the other waters used. If the cost of all other forms of treatment are included the total will be well over $500,000.

Nearly all waters used by railroads in Iowa are highly mineralized,

or to use a common expression they are "hard waters." The State of Iowa is deeply covered by drift and soil composed chiefly of finely divided material which contains considerable amounts of calcium sulphate and other more soluble compounds. The rainfall comes in contact with this material and that portion of the rainfall which becomes ground water must pass through it, giving the water opportunity to take up mineral matter. Only small superficial sand areas in the State take up the rainfall and transmit it as soft water to wells or streams. The deep rich soil also contributes indirectly to the mineralization of water, as nearly the whole area is covered with vegetation of some sort, and the soil contains large amounts of decaying vegetable matter. An unusual amount of carbon dioxide is thus supplied to the water at the surface which enables it to dissolve large amounts of calcium and magnesium carbonates.

Iowa rivers contain very much greater amounts of mineral matter in solution than the rivers of the whole continent. The average total solids of the Des Moines, Cedar and Iowa Rivers as determined by analyses of the United States Geological Survey are 16 grains per gallon while the average of the river waters of the continent is 9 grains per gallon. The total solids for the Iowa rivers as given above include only the dissolved mineral matter; if the suspended matter is included the total matter carried by the river waters is more than 32 grains per gallon.

The same general agreement is found between the mineral content of the waters of the rivers and that of the best deep wells. A wide variation is found in the well waters, the best wells containing about 15 grains total solids while the worst waters contain 60 grains or more. Apparently an increase in the mineral content of the waters is found from the northeast to the southwest corner of the state.

It is not the intention to leave the impression that the waters of Iowa are the worst in the country, but they are of such a nature that with few exceptions they can be improved for boiler use by treatment.

The railroads of Iowa used these waters in their natural state for many years and while boiler troubles due to bad water conditions were extensive and annoying they were looked upon prior to twenty-five years or so ago as a necessary evil, and efforts toward improving water conditions consisted chiefly of the application of soda ash and various compounds.

As the tonnage of trains increased and faster train schedules were adopted it became necessary to use heavier locomotives carrying higher

steam pressures and the question of improved water supply became more important, and in fact was an economic necessity.

The necessity for the complete treatment of boiler waters in Iowa was probably most forcibly brought to the attention of the railroads in 1901 and 1902. The record of one Iowa railroad indicates that train movement was seriously interrupted during the winter of 1901 and 1902 on account of bad water. During the month of January 1902, 109 engine failures were reported on the Iowa lines of this road, 91 of which were due to leaky flues. These failures affected 145 trains from one to four hours each. It was apparent that the condition of the engines was growing rapidly worse, as during the first ten days in February 1902, 56 engine failures occurred, nearly all of which were due to leaking flues. Another railroad operating in Iowa reports that during the eleven months from August 1902 to and including June 1903, a total of 583 engine failures occurred on their Iowa Lines, all of these failures being due to leaking locomotives. These conditions undoubtedly hastened the construction of complete water softening plants, and it is gratifying to note that the treatment of water on the railroads in question has improved boiler conditions to such an extent that today an engine failure is almost unknown.

The Chicago and Northwestern Railway was the pioneer in water treatment in Iowa. Their first plant was erected at West Side early in 1903. They also built a plant the same year at Council Bluffs, Iowa. The Illinois Central followed with the construction of water treating plants at Dyersville, Manchester and Peosta in 1904. Other roads followed closely on the heels of the Northwestern and Illinois Central in the contruction of water treating plants until at the present time, as previously stated, there are 98 plants on six of the principal railroads in Iowa, representing nearly 7 percent of all water treating plants throughout the country.

These figures take into considration only that proportion of the water given complete treatment by the lime and soda process. There is very little water used by railroads in Iowa that is not treated in some manner, as where complete treating plants are not provided boiler compounds, soda ash and other chemicals are used.

For example, while only 90 percent of the water used on the Illinois Central in Iowa is given complete treatment, the balance of the water is treated by means of compounds, this treatment being applied direct to roadside tanks on that portion of the line from Sioux Falls, S. D., to Ft. Dodge, Iowa (not including Cherokee where we

have a complete treating plant) and by compounds applied directly to engine tanks from Cherokee to Onawa and from Manchester to Cedar Rapids.

SAVINGS BY TREATMENT

The Water Service Committee of the American Railway Engineering Association made a study of the saving in locomotive operation through the treatment of water on the lines of the Chicago, Milwaukee, St. Paul & Pacific and Illinois Central in Iowa. The Milwaukee figures include a portion of their lines in South Dakota while the Illinois Central figures were confined to the State of Iowa.

The results of these investigations show that the annual decrease in expense per locomotive which may be attributed to water treatment was $1,568.12 per locomotive per year on the Milwaukee, while on the Illinois Central the average saving was $2,732.19. The Illinois Central System operates approximately one hundred fifty locomotives in Iowa. Therefore, the annual saving effected through the treatment of water is estimated at $409,828.50.

It is estimated that at least 30 percent, or approximately 190 billion gallons, of the water used by the railroads is purchased. The rates paid range from 3 cents up to $1.00 per thousand gallons depending upon the location and the amount of water consumed. The average cost is somewhere between 6 and 10 cents per thousand, or an annual expense of approximately $19,000,000.

The use of acid coagulants in the treatment of many city supplies has added very materially to the problems of the railway water supply officer.

The sulphate hardness of the water is increased in nearly every case where acid coagulant is used. In the majority of cases the total incrusting solids of the water is increased and in many instances the effect is to decrease the carbonate hardness and increase the sulphate hardness. In the case of the so-called border line waters of moderate hardness and a balanced carbonate-sulphate hardness the result of the treatment is to render these waters highly corrosive when used in boilers or hot water systems.

(*Presented before the Iowa Section meeting, October 26, 1932.*)

COTTON CAULKING YARN

By W. M. Rapp

(*Superintendent, Construction and Distribution, Atlanta, Ga.*)

AND

Paul Weir

(*Superintendent of Filtration, Atlanta, Ga.*)

During September, 1930, approximately four miles of 16- and 12-inch C. I. water pipe were laid in Peachtree Road mainly for the purpose of supplying water to the U. S. Veteran Hospital, #48 and to Oglethorpe University.

This pipe was brought from the cars and distributed along an asphalt street and did not remain on the ground more than a few days before being installed. Each length of pipe was thoroughly swabbed and cleaned before being laid and unusual care was taken to keep the pipe clean and sanitary. Before placing this main in service, it was filled, emptied and washed out through the blow-outs, and bacteriological analyses made of the water.

Results of these analyses, however, did not comply with the U. S. Government regulations so the mains were again emptied and washed out through the blow-outs and a second analysis made with practically the same result as before.

A three-quarter tap was then made behind the 16-inch valve controlling this new main and through this tap chlorine gas was injected while filling the main. The water so treated with chlorine was allowed to remain in the new main for a period of 24 hours after which the line was emptied and washed out through the blow-outs and filled with sterile water as in each case before. Analyses still showed the water to be impure as compared with Government standards, and it was necessary to repeat this procedure five times before samples of water complied with Government regulations.

The time consumed was more than two weeks and was necessarily costly to the City.

Suspicion was directed toward the jute used in caulking this line, and samples of yarn were obtained from different dealers in Atlanta.

Mr. Paul Weir, Superintendent of the Atlanta Water Works Filter Plant, made bacteriological analyses of these samples. The results of these analyses are shown in Appendix A by Mr. Weir.

For years I have felt that jute, as commonly used in water works practice was, by the very nature of its curing, preparation and handling, an impure and unclean product and could contaminate water. Our experience as just related fully confirmed suspicions in this respect. Subsequent research developed similar experiences in other cities and the fact that this matter had been the subject of investigations by eminent chemists and engineers, but without suggestion as to a remedy. A list of these investigators is attached to this paper.

BRAIDED COTTON YARN

Not knowing of any sanitary substitute that had been offered for jute or hemp packing, we consulted Professor C. A. Jones, in charge of the Textile Department of the Georgia School of Technology, and with his coöperation a braided cotton yarn was developed for the purpose.

It will be recalled that lead spacing in both DeLavaud and Sand Cast pipe is 0.4-inch up to and including 14-inch diameter pipe, and 0.5-inch from 16- to 24-inch inclusive; and for Sand Cast pipe 0.5-inch from 24-inch to 60-inch inclusive.

Developments up to the present time indicate the necessity for only two diameters of yarn, namely, $\frac{5}{8}$- and $\frac{7}{8}$-inch respectively, the $\frac{5}{8}$-inch being adapted to either class of pipe up to and including 14-inch and $\frac{7}{8}$-inch for sizes above 14-inch.

In all cases the yarn is of greater diameter than the width of the lead spaces, and is uniform in diameter throughout the entire length.

Thorough elasticity of the yarn insures adaptability of the yarn to all inequalities of pipe and bells, and to all conditions incident to pipe laying.

When compressed with a yarning tool the cotton yarn makes a solid, uniform and evenly spaced joint providing an even depth of lead, Leadite or other joint material around the entire pipe circumference, and thus, under pressure, a hydraulically packed semi-water-tight joint. Our experience with lead and Leadite joints confirms this assertion.

The fifty pound bale of yarn as shipped from the mill is wrapped in paper with an outer covering of heavy cotton sewed on as a protection against contamination at all times.

When and as needed the yarn is uncoiled from the center of the bale through a hole in the end of the covering and may be cut in required lengths at the place of storage and sent to the crews on the job.

The main conclusions which may be drawn with respect to this yarn are:

1. Cotton is a "sun-light" home-grown product.
2. It is sanitary and can be kept in this condition.
3. It will lower the cost or preparing for and yarning the pipe.
4. Its construction precludes protrusion of yarn and joint materials into the pipes.
5. It insures a uniform depth of joint material, whatever may be used, thereby lowering a principal cost in making joints.
6. It insures equal spacing of cut pipe without beads.
7. Its use in cast iron soil pipe (sanitary plumbing) guarantees a perfect joint.
8. It speeds up the laying of pipe.
9. It reduces joint leakage to a minimum.
10. All advantages set out for use with water pipe apply with equal force to gas joints.

It is with full appreciation that we acknowledge the assistance rendered by:

Professor C. A. Jones of the Georgia School of Technology.
Mr. S. E. Linderman of the Research Department of the U. S. Pipe and Foundry Co.
Mr. W. H. Weir, Engineer, Georgia State Board of Health.
Mr. W. Zode Smith, General Manager of the Atlanta Water Works.

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Appendix A

Bacteriological Tests

This section of the paper on cotton caulking yarn deals with the method and procedure of conducting the various bacteriological analyses which have paralleled Mr. Rapp's work for the past two years. No attempt will be made to cite results of any specific test conducted, but cumulative data will be referred to throughout.

Much difficulty was experienced in disinfecting the four miles of 12- and 16-inch cast iron water main laid in Peachtree Road. However, intermittent flushing and disinfecting with chlorine gas finally produced a pure drinking water that complied with the U. S. Treasury Standards. The chlorine content was varied from 2 to 20 p.p.m. and the contact periods from 24 to 48 hours. The low-range Atlanta turbidimeter and floc detector, used in conjunction with this work, indicated that organic matter was not being carried over from the connecting tubercled feeder main into the newly laid lines. It was evident, therefore, that the persistence of contamination in the sterilized main was caused by the presence of bacteria from the Coli-Aerogenes group which originated in the jute yarn used in making the pipe joints.

There are various grades of braided and unbraided jute yarn on the open market. It may be obtained in a tarred, untarred, oiled or unoiled form.

The method of examination is similar to that used by Spaulding of Springfield, Illinois. "One-tenth (0.1) gram of fibre is taken aseptically from an inner strand of the twist and placed in a flask containing 100 cc. of sterile distilled water. This is allowed to stand over night at room temperature (65°F.) after which a series of dilutions is planted in lactose broth." Complete confirmation methods were employed as directed in "Standard Methods."

The results of examination of eight samples of yarn are given in table 1.

The tarred jute and the round cotton samples were sterile, while

the remaining six jute samples revealed bacteria of the Coli-Aerogenes group from 4,500 to 270,000,000 per pound.

It is impracticable to use tarred jute for water pipes because of the objectionable odor imparted to the water.

The cotton caulking yarn is not only free from pathogenic bacteria, but also offers greater hydraulic possibilities in the joint than either the braided or unbraided jute.

Although the original cost of cotton caulking yarn will undoubtedly be slightly higher than that of jute, the reduced cost of disinfection

TABLE 1

Coli-aerogenes count and sterilization costs on caulking yarns

NUMBER	DESCRIPTION	COLI-AEROGENES				DISINFECTION COST	
				Average per joint		16-inch line	
		Per gram	Per pound	3–14-inch pipe	16–48-inch pipe	Per joint	Per mile
						cents	*dollars*
1	Braided jute	10	4,500	2,000	14,500	10	45.00
2	Unoiled jute	20,000	9,000,000	3,960,000	29,000,000	15	70.00
3	Tarred jute	0	0	0	0		
4	Untarred jute	200,000	90,000,000	39,600,000	290,000,000	20	90.00
5	Untarred jute	100,000	45,000,000	19,800,000	145,000,000	15	70.00
6	Untarred jute	350,000	158,000,000	69,500,000	509,000,000	26	117.00
7	Unoiled jute	600,000	270,000,000	118,800,000	870,000,000	32	144.00
8	Round cotton	0		0	0	9	41.00

0.44 pound (average) used per joint, 3- to 14-inch pipe.

3.22 pounds (average) used per joint, 16- to 48-inch pipe.

One mile 16-inch pipe = 450 joints. Based on 10 feet per length and allowing for fittings.

and the added factor of safety will materially reduce the ultimate price.

The disinfection cost figures on the 16-inch main apply particularly to Atlanta's system when chlorine gas is used as the sterilizing agent. The cost includes labor, chlorine gas and water. The Atlanta cost should not be construed as a criterion for other systems since the circumstances surrounding each installation present individual problems.

Foreign conditions peculiar to the production and shipment of jute do not comply with American standards of sanitation; whereas the cotton caulking yarn, developed by Mr. Rapp, is a native Southern

product, manufactured under sanitary conditions, and it should offer a new outlet for several thousand bales of cotton.

DISCUSSION

MR. COBB: Last July I was in Birmingham and talked to Mr. Van Devere who was chief engineer there at that time. He had done a little research work and had developed a braided cotton yarn, a few pounds of which he gave me. At that time I was superintendent of a small plant in Kentucky and we were planning to lay several hundred yards of pipe, so I took this back to Kentucky and put in alternate cotton and jute joints. We were not particularly interested in bacterial tests, but it was more for testing what it would do. I put it in according to instructions and poured as little lead as we could. We left the trench open for about thirty days on an unused street and nearly every one of the leadite joints made up with other materials leaked while the joints made up with this cotton yarn never leaked a drop. Mr. Van Devere, I believe, was mainly interested in developing this cotton yarn as an outlet for cotton in the South and he was not, I think, looking at it from a sterile standpoint. I advised him of my results, but he has since died and I do not know what has been done further in this experiment.

MR. RAPP: This yarn we have and the yarn you spoke of are entirely different, they are made by two different methods. The yarn you speak of is woven in and out, braided like a whip.

Of course, in this work the main object is the get as much material density inside the joint as possible. Nearly all of us have simply thought that the yarn was something cheap to make a stopper and prevent the lead running into the pipes. No serious intention to make the jute form a part of the joint has ever been entertained.

MR. SIMONS:[1] Cotton expands very much more than jute in water, does it not?

MR. RAPP: Yes.

MR. SIMONS: My idea was that on account of the absorption of the material it would make a tighter joint than jute.

[1] U. S. Pipe and Foundry Company, Birmingham, Ala.

MR. RAPP: The minute the cotton yarn absorbs the water it begins to hydraulically seal. When we pour a lead joint, the lead contracts and we have a space between the lead and the pipe. With this yarn, when it was first put in, it leaked. In fifteen minutes it took up 75 percent and in an hour 90 percent. We connected the section of pipe on which this yarn was used to a test pump and applied a hydrostatic test of 300 pounds. When this pressure was applied the leak immediately stopped.

MR. WEIR:[2] That is an uncaulked joint?

MR. RAPP: Yes. Each of the uncalked joints withstood 300 pounds pressure without a leak. There is no intention to leave the lead joints uncalked, but simply to demonstrate that the cotton yarn will reduce leakage.

MR. STILLWELL:[3] I have had the pleasure of doing a little work with Mr. Rapp in connection with the promotion of this yarn and he gave me the privilege of laying about 200 feet of pipe with leadite using this $\frac{5}{8}$-inch cotton caulking yarn. Immediately after these joints were poured, which was done by myself, we put 300 pounds pressure on the main and, much to my surprise, only a few had any leaks at all and they were very slight. I can come to no conclusion but that the cotton swelled to such an extent when the water was put on it that it sealed up the joint. I believe Mr. Rapp has a product, which is not only applicable to lead, but to other types of jointing compounds. It is especially capable of overcoming the leakage incident to the use of sulphur base jointing compounds of any kind.

(*Presented before the Southeastern Section meeting, April 6, 1933.*)

[2] State Department of Public Health, Atlanta, Ga.

[3] Leadite Company, Atlanta, Ga.

LIME SLAKING

By E. E. Harper

(*President, Omega Machine Company, Kansas City, Mo.*)

The subject of lime slaking is of interest on account of the ever increasing use of lime in water purification and softening plants, and the call for increased efficiency in such plants. Ten years ago lime was used only in a few of the larger plants. Today hundreds of plants, large and small, are using lime in water purification and treatment process, and many more plants will soon fall in line.

Lime is used in a water purification plant for the following purposes:

1. To assist in or improve coagulation.
2. To soften the water by removing temporary hardness.
3. To remove iron by absorbing CO_2.
4. To prevent corrosion by absorbing CO_2.
5. To prevent vegetable growths by the removal of CO_2, which is as necessary for vegetable growth as oxygen is for animal growth.

KINDS OF LIME

Lime is purchased in either of two forms, quicklime or hydrated lime. Quicklime is burned limestone as it comes from the kilns. If the limestone is burned in large lumps, these are crushed at the kiln and the lime may be furnished in any size from 2 inch lumps down to material passing a 10-mesh screen. Sometimes the limestone is crushed before it is burned and is then burned in rotary kilns. Such lime is called pebble lime.

Hydrated lime is manufactured by adding one ton of water to three tons of quicklime. The water causes the quicklime to break down into a fine powder which is commonly known as hydrated lime. The purchaser of four tons of hydrated lime buys three tons of lime and one ton of water, for which the average price in this vicinity in carload lots is about $12.00 per ton.

As the water works produces and sells water for about 5 cents per ton, it is rather expensive to pay the lime manufacturer $12.00 per ton for the water which he uses in making hydrated lime.

STORAGE

For large plants quicklime is generally purchased in bulk in carload lots and is unloaded and stored in overhead bins by pneumatic equipment. For medium sized and small plants the crushed quicklime can now be purchased in multi-wall paper bags holding about 90 pounds each. The lime will store very nicely in these bags for a period of from 30 to 60 days. If a longer storage period is required, dry, air-tight bins should be provided. Hydrated lime is generally furnished in 50 pound paper bags and will store for a long period of time.

SELECTION OF LIME

On account of the difficulty in storing quicklime and the fact that special equipment is required for slaking the lime, it is generally more satisfactory and economical to use hydrated lime in small plants where the requirement does not exceed 500 pounds of lime per day. If the amount of lime used exceeds 500 pounds per day, the use of quicklime will generally be more economical.

Of course, there are many places where 500 pounds per day would not represent the proper dividing line between hydrated lime and quicklime, but this figure represents the average under present conditions.

RELATIVE COSTS

In a general way it may be stated that the cost of treating water with quicklime is about three-quarters the cost of treatment with hydrated lime, and that a saving of 25 percent may be obtained by using quicklime instead of hydrated lime.

There are many small plants which are now using a limited amount of lime in treating water of such a character that considerably better results would be obtained if more lime were used.

Many of these plants could change to quicklime and increase the lime treatment about 25 percent without any increase in the cost of of operation and with a decided improvement in the quality of water produced.

SOFTENING WITH LIME

Most of the waters in this section of the country are rather hard and most of the hardness is temporary or carbonate hardness, caused by dissolved limestone in the water. This temporary hardness may be removed by adding lime to the water.

We shall not attempt to explain in this paper how lime softens water, but will state that, in a general way, one grain of quicklime added to water containing dissolved limestone or carbonate hardness will remove one grain of hardness from the water.

It may be mentioned, in passing, that lime and activated carbon are the only chemicals in general use in water purification plants which can be added to the water in excessive amounts without injury to health. Of course, if too much lime is added to the water the taste will be unpleasant, but illness cannot result from drinking an excessive amount of water over-treated with lime or activated carbon. This cannot be said of any other chemicals used in water purification work.

LIME SLAKING

Slaking lime, in water works practice, is the process by which sufficient water is added to quicklime to satisfy its thirst or chemical demand for water, with the further addition of water in excess of that required for slaking to make a milk-of-lime mixture for suspension (not a solution) which can be conveniently handled and applied to the water to be treated.

Technically to slake 1 pound of quicklime to the dry or hydrated state requires about $\frac{1}{3}$ pound of water. In practice it requires from 3 to 5 pounds of water to slake 1 pound of quicklime and make a milk-of-lime mixture that can be handled satisfactorily.

Considerable heat is generated by the combination of the water and the lime, probably in proportion to the available calcium oxide content of the lime, and if the temperature of the water used for slaking is not below 60° Fahr. and the water supply is properly controlled enough heat may be generated to maintain a satisfactory temperature in the slaker.

From tests we have made we conclude that 1 pound of good quicklime will generate about 350 B.t.u.'s or heat units. We hope that some of our chemist friends will do some investigating along this line and develop a method by which we can measure the efficiency of the slaking process and the chemical value of the lime by keeping a record of the amount of lime used, the amount of water required for slaking, and the temperature generated and maintained in the slaker. Such a test would be of considerable value to the water works operator.

The slaking process is greatly hastened and the efficiency of the slaking is improved by using warm water in the slaker. In large

plants heat recovery apparatus is sometimes installed for recovering the waste heat from the milk-of-lime solution discharged from the slaker, but this considerably complicates the installation and is not justifiable in small plants.

In other plants waste heat from the carbon dioxide plant or from the heating plant or waste steam from the power plant is frequently available, and may be used to advantage to maintain the high temperature so necessary for proper slaking.

Early methods

The earlier water purfication and softening plants using quicklime resorted to batch slaking. In this process the lime was placed in a suitable tank or vat, water was added and the mixture was stirred either by hand or mechanical means until the lime was slaked. The slaked lime was then drawn off into another tank, more water was added to dilute the mixture, which was then fed to the water to be treated.

An interesting modification of this method was that in use in the plant at Grand Rapids, Michigan for about ten years. A batch of about 500 pounds of quicklime was placed in a large concrete mixer and water was added while the mixer was revolved. In about five minutes the entire batch of lime was slaked and the mixture was then dumped into a large tank where more water was added and the whole mass was kept in agitation by a mechanical agitator. The milk-of-lime was drawn off from this tank through a solution box and was added to the water to be treated.

There was a considerable escape of dust and vapor from the concrete mixer during the operation and an intricate system of exhaust blowers and ducts was installed to remove the dust and vapor.

This system was replaced about three years ago with a device for continuously feeding and slaking the lime, which resulted in a saving of about $5,000.00 per year on account of the greater efficiency obtained through the continuous slaking process.

Present methods

Within the past few years dry chemical feeding machines have been developed which will feed crushed quicklime in any size from 2 inch lumps down to powdered form. Continuous slaking machines have also been developed which will continuously slake the quicklime after it is discharged from the feeder and deliver a milk-of-lime solution which is ready to be applied directly to the water to be treated.

When lime slaking was first commenced, very little attention was paid to the amount of water used for slaking purposes and many of the older types of slakers are of such mechanical construction that it is impossible to operate them without using an excessive amount of water.

Other slakers have been developed which permit the use of a minimum amount of water for slaking the lime and the users of such equipment soon found that a much higher efficiency was obtained by slaking at a rather high temperature.

This fact has long been known to chemists and others who have experimented with lime slaking, but the trouble has been to get equipment that would operate continuously and satisfactorily when slaking the lime at high temperature.

That problem has now been solved and it is possible to slake the lime continuously at the high temperature which is necessary for the best results, without any escape of dust or vapor and without the dirt and mess which characterized the operation of the old time slaking equipment.

High temperature important

The slaking of lime is a chemical reaction and when it is conducted at a low temperature the process is sometimes very slow. In fact, it may continue for weeks and months.

This is best illustrated by the experience of plasterers who have found that where a freshly slaked lime was used for plastering walls that after the work was finished small pits would occur in the wall. In fact, the face of such a wall looked as if it had just recovered from a bad case of small-pox.

This pitting was due to the further slaking of certain particles of the lime after the plastering was completed and was sometimes delayed for many months

In many of our large cities commercial lime slaking plants are in operation In these plants the quicklime is always slaked at high temperature and after being slaked the mixture, which is about the consistency of thick cream, is stored in large vats and is allowed to age for at lest six weeks before it is used Such aging is absolutely necessary in order that every particle of lime will be completely slaked before it is used

The higher the temperature at which the lime is slaked, the more complete the reaction will be With a slaking temperature of between 175° and 200° Fahr., it may be said that for all practical purposes in

water works practice the lime can be completely slaked in a period of less than five minutes. Therefore, a slaker which provides for a retention of 15 or 20 minutes and slaking at high temperature will completely slake the lime.

After slaking, some particles of certain limes still retain a somewhat granular character and in this condition will not go into solution in the water.

It is highly important, therefore, that the slaking mechanism be so designed that these particles will be kept in the slaker for a considerable period of time and that they be subjected to a grinding or crushing action in the slaker which will break up the granules of material and thereby make the lime available.

If lime is slaked at low temperature, the resulting particles are rather coarse and after the milk-of-lime leaves the slaker these coarse particles dissolve very slowly. On the other hand, if the lime is slaked at high temperature the resulting particles are very fine and go into solution more readily.

MIXING MILK-OF-LIME WITH THE WATER TO BE TREATED

At this point it may be well to mention that it is not easy to get the lime into solution in the water to be treated. Cold water will only dissolve about 60 or 80 grains of lime per gallon and in order to dissolve this amount of lime, considerable agitation is necessary.

A milk-of-lime solution, whether made by using hydrated lime or quicklime, contains the fine, undissolved particles of lime in suspension and these must be thoroughly stirred with the water to be treated for a considerable period of time before they are all dissolved.

If the agitation is not thorough and complete, many of these particles of lime will settle to the bottom of the basin and will be withdrawn as sludge and wasted. Therefore, in any method of treatment involving the use of lime it is highly important that thorough mixing for a considerable period of time be used in order that the best results may be obtained.

The mixing period, in our opinion, should never be less than five minutes and on an average fifteen minutes is much better.

SUMMARY

1. Lime is one of the most important chemicals used in water purification and treatment work. It is used for a wider variety of purposes than any other chemical in this work.

2. Three tons of quicklime has the chemical value of four tons of hydrated lime, and it can be purchased at about the same price per ton as hydrated lime.

3. In water softening practice about one grain of quicklime is required to remove one grain of temporary or carbonate hardness from the water being treated.

4. Quicklime can be used advantageously in many plants which are now using hydrated lime at no increase in the cost of chemicals and with a decided improvement to the water being treated.

5. With present practice quicklime can be used advantageously in plants requiring about 500 pounds of hydrated lime per day. In the smaller plants hydrated lime can best be used.

6. Lime slaking should always be carried on at a fairly high temperature, say between 175° and 200° Fahr. A liberal retention period should be allowed for the slaking process and the slaking equipment should be so arranged that particles of lime which are not readily slaked or retain their granular form may be kept in the slaker for a considerable period of time so that they may break down and the lime therein may be released.

7. Adequate means should be provided for thoroughly mixing the milk-of-lime with the water to be treated. A decided waste of lime results where the mixing is not complete or is not carried on for a sufficiently long period of time. This applies both to the use of quicklime and hydrated lime.

8. Waterworks chemists may render a valuable service by devising a simple and accurate method by which the plant operator can determine the efficiency of the slaking process and the chemical value of the lime being used.

(*Presented before the Missouri Valley Section meeting, October 26 1932.*)

PHOTODISCOLORATION OF ORTHOTOLIDINE AND ARTIFICIAL STANDARDS FOR FREE CHLORINE TEST IN WATER

By W. S. Davis and C. B. Kelly

(From the Division of Laboratories and Research, State Department of Health, Albany, N. Y.)

As deterioration of the reagent used may seriously affect the accuracy of the determination of free chlorine in water, it seemed important to find out whether the discoloration and precipitate which we have observed in orthotolidine on its exposure to sunlight actually impaired its value. Ellms and Hauser (1) have found that the reagent does not deteriorate on standing; they do not mention the effect of direct sunlight, however, or of other extreme conditions.

In order to ascertain this, one liter of orthotolidine solution was divided in half and put into clear glass bottles. One portion was exposed to south light and the other was stored in a dark cupboard.

These two solutions were used at various intervals in free chlorine determinations. The color of the ortholidine reagents was also observed. The results of these observations are given in table 1. The reagent exposed to the light showed a discoloration at the end of about six weeks, and after two months, the solution became unreliable. The solution stored in the dark for eleven months showed no evidence of deterioration.

Similar observations were made on the dichromate-copper-sulfate standards used in the determinations. The standards exposed to light and those stored in the dark were compared with, and evaluated in terms of, freshly prepared standards. The results of these comparisons are given in table 2. After seven months, the standards, especially the lower ones, had deteriorated sufficiently to cause an error in the test. Those kept in the dark have shown no change after eleven months. The results in tables 1 and 2 are reported in two significant figures only, since the experimental error would not allow interpolations beyond this point.

It is evident that both the reagent and the standards used in the determination of free chlorine are affected by exposure to light. Of

TABLE 1

Stability of the orthotolidine reagent: Amounts of chlorine found in water samples tested with reagent stored under varying conditions

DATE TESTED	EXPOSED TO LIGHT*		KEPT IN DARK*		FRESHLY PREPARED
	Free Cl	Condition of solution	Free Cl	Condition of solution	Free Cl
1933	*p.p.m.*		*p.p.m.*		*p.p.m.*
1.4	0.04	Colorless	0.04	Colorless	
1.28	0.20	Colorless	0.20	Colorless	
2.8	0.06	Colorless	0.06	Colorless	
2.23	0.05	Sl. yellow	0.05	Colorless	
3.16	0.03	Brown; sediment	0.06	Colorless	0.06
3.16	0.70	Brown; sediment	0.70	Colorless	0.70
4.8	0.90	Brown; sediment	1.0	Colorless	1.0
4.8	0.01	Brown; sediment	0.04	Colorless	0.04
5.9	0.00	Brown; sediment	0.04	Colorless	0.04
5.9	0.22	Brown; sediment	0.25	Colorless	0.25
5.9	1.0	Brown; sediment	1.1	Colorless	1.1
8.25	0.00	Brown; sediment	0.05	Colorless	0.05
8.25	1.0	Brown; sediment	1.2	Colorless	1.2
11.22	0.07	Brown; sediment	0.12	Colorless	0.12

* Prepared January 4, 1933.

TABLE 2

Stability of dichromate-copper-sulfate standards

Results are expressed as parts per million of chlorine

DATE TESTED	FRESHLY PREPARED	EXPOSED TO LIGHT*	STORED IN DARK*	DATE TESTED	FRESHLY PREPARED	EXPOSED TO LIGHT*	STORED IN DARK*
1933	*p.p.m.*	*p.p.m.*	*p.p.m.*	*1933*	*p.p.m.*	*p.p.m.*	*p.p.m.*
1.4	0.1	0.1	0.1	7.15	0.1	0.1–	0.1
	0.2	0.2	0.2		0.2	0.2–	0.2
	0.3	0.3	0.3		0.3	0.3–	0.3
	0.5	0.5	0.5		0.5	0.5	0.5
4.8	0.1	0.1	0.1	8.15	0.1	0.09	0.1
	0.2	0.2	0.2		0.2	0.18	0.2
	0.3	0.3	0.3		0.3	0.29	0.3
	0.5	0.5	0.5		0.5	0.5–	0.5
6.15	0.1	0.1	0.1	11.22	0.1	0.07	0.1
	0.2	0.2	0.2		0.2	0.18	0.2
	0.3	0.3	0.3		0.5	0.5–	0.5
	0.5	0.5	0.5				

* Prepared January 4, 1933

the two, the reagent is the more quickly deteriorated and should be stored in amber bottles. In any event, both standards and reagent should be protected from light when not in use.

REFERENCE

(1) ELLMS, J. W., AND HAUSER, S. J.: Orthotolidine as a reagent for the colorimetric estimation of small quantities of free chlorine. Jour. Indust. & Engin. Chem., 1913, 5: 915.

TASTE AND ODOR PROBLEMS AT CHESTER, PENNSYLVANIA

By Rennie I. Dodd

(*Chemist in Charge, Chester Water Service Company, Chester, Pa.*)

At Chester the water is taken from the Delaware River through two intake pipes extending into the river to a point near the navigation channel. The water flows by gravity into an intake well where there is a mechanically operated self-cleaning curtain screen. In the screen house there is also installed an ammoniator and a dry feed machine for feeding bleaching clay (Fuller's Earth).

From the intake well the water is pumped through banks of 3-inch Spraco aerator nozzles. The central line of nozzles is set vertically, while the outside lines are set at an angle of 45 degrees discharging toward the center.

The aerated water falls into a rectangular metal pan and flows through a central collector and mixer where chlorine is applied before entering the chlorine contact tanks.

The two chlorine contact tanks are circular steel hopper bottomed tanks located below and supporting aerator pan. The water enters near the bottom through baffled bell inlet nozzles where it is given a tangential start and flows upward and inward to a central riser pipe protected by a circular baffle to hold back any oil scum. These tanks provide 30 to 45 minutes contact period.

From this point the water flows into any or all of the three steel hopper bottom mixing tanks located in the two story chemical storage house, which also houses a laboratory, office and chemical machines. The piping from the chlorine contact tanks to the mixing tanks is so arranged that all the water passes through an open flume into which dry feeders apply the coagulating chemicals. The water enters the mixing tanks through tangential nozzles near the bottom and leaves through central riser pipes. There is from 20 to 30 minutes detention in mixing tanks.

From the mixing tanks the water flows into the two rectangular concrete settling basins, where there is from three to four hours detention period.

After settling the water is filtered through rapid sand filters, is again chlorinated, and the pH corrected by the addition of hydrated lime.

The filters are conventionally designed rapid sand or mechanical filters equipped with Wheeler bottoms, Simplex Controllers, etc. There are ten units having a combined capacity of 12,500,000 gallons per day, when operated at a rate of 125,000,000 gallons per acre per day. All other units of the plant are of proportionate capacity.

OPERATING PROBLEMS

The operating problems at Chester are numerous, but the taste and odor problem is so dominating that all other problems diminish in importance. The contributing factors to the taste and odor problem are too numerous to enumerate, but in general they are industrial wastes and sewage, the oil refineries being the worst offenders.

In combating tastes and odors every known method of treatment has been tried with varying degrees of success. The most satisfactory treatments so far found are those indicated by the plant description. Continued and special studies of the various treatments used have convinced us that for this particular supply, the treatments now used accomplish the following results.

Fuller's earth or bleaching clay is beneficial in removing tastes and odors due to oils. It results in a stronger and more adsorptive floc. It tends to stabilize sludge in the basins, thereby preventing decomposition and the production of foul odors within the sludge. Aeration removes most of the odor due to the more volatile oils and entrapped gases. The need for aeration is also indicated by oxygen deficiency of the water and the high oxygen consuming power.

Prechlorination with contact oxidizes odors due to organic matter and tends to condition the water for coagulation.

The absorbing power of a well formed floc, is well recognized.

Filtration, while an important step in the process, otherwise does not accomplish a great deal in the way of odor removal.

To illustrate the effectiveness of the different treatments during a recent study using the dilution method for odor determination it was observed that the process of aeration alone reduced a raw water odor from 200 to 100 and that the process of prechlorination reduced the odor of the aerated water from 100 to 8, demonstrating that after all the greatest part of odor removal is accomplished by these two treatments.

ODOR DETERMINATIONS

Since it is not a great deviation from the problem of tastes and odors to the problem of methods and technique of determination of odors, it might be well to mention at this point how we have been able to overcome to a very great extent the unsatisfactory and rather unscientific procedure of the old standard method, first devised and used in New England for water supplies having mild taste and odor difficulties.

It was intended to permit an evaluation of the intensity of odors in water more particularly from the point of view of the consumer. The intensity was estimated by the observer and arbitrarily assigned a numerical value ranging from 0 to 5. The number intensity was followed by a letter or symbol indicating the nature of the odor. It is apparent that no two observers could be expected to check in their estimation of the intensity of the same odor.

In September, 1931, Charles H. Spalding of Springfield, Illinois, proposed the dilution method for the determination of odors in water.[1] Briefly this method consists in diluting smaller and smaller size samples of water to be tested until a dilution is obtained where no odor is perceptible. The "odor value" or "threshold number" is the number obtained by dividing the total volume of the dilution in CC by the number of CC of the sample contained in that dilution where the odor just disappears.

The original technique described by Spalding has been modified somewhat by Mr. Baylis whose procedures are described by Mr. Oscar Gullans in THE JOURNAL for July, 1933. Baylis adopts the practice of adding 1 (one) to the "threshold number," obtained by the Spalding method in order to take care of a minor discrepancy which occurs in the largest volume examined.

The latest contribution to the dilution method is a scientific study by Professor Gordon M. Fair on "The Determination of Odors and Tastes in Water."[2] This study approaches the matter from a fundamental standpoint. It is maintained that the sense of taste is only able to detect four different reactions; namely, sour, salty, bitter, and sweet. The other sensations of taste we obtain from substances may be traced to odors, temperature, touch and chemical sensations.

By examination of the physiological factors involved Professor Fair comes to the conclusion that the sense of smell is capable of

[1] American Journal of Public Health, vol. 70, No. 9.
[2] Jour. New England W. W. Assoc., vol. 47, No. 3.

detecting differences of magnitude in ratios only as great as 2:1. He feels that a dilution for the odor test should be made on this basis; namely, as 2, 4, 8, 16, 32, etc. The odor scale thus established is an exponential scale to the base 2, the exponents being 0, 1, 2, 3, 4, 5, etc.

This approach to the matter reconciles the Old Standard Method numbers directly with the new dilution method. It is proposed to call these exponents by the symbol of po, thus po4 standing for an odor "threshold" intensity of $2^4 - 16$. The table below will illustrate the relationship between the standard method values, the "threshold" numbers and p^0 values:

STANDARD METHOD INTENSITY	P^0	THRESHOLD VALUE
1	1	2
2	2	4
3	3	8
4	4	16
5	5	32
	6	64
	7	128
	8	256
	9	512
	10 etc.	1,024 etc.

It should be noted that there is no limit to the size of the numbers which can be obtained by the dilution method, whereas the maximum obtainable by the Standard Method is 5.

In the work at Chester an effort has been made to incorporate the best features of all these methods and to simplify them as much as possible. All dilutions are prepared in a volume of 200 cc. contained in a 300 cc. Erlenmeyer flask. A series of dilutions are prepared, including a blank, and the technique is to shake each sample in turn and observe its odor, beginning with the smallest volume of sample and working up through the series. As soon as a definitely recognizable odor is obtained, the dilution thereof is noted and the "threshold number" or "odor value" recorded, together with the type of odor observed.

The same series of flasks is placed upon a hot plate, the flasks are closed by means of watch glasses and heated to about 65°C., when the odors are again observed in a similar manner to arrive at a hot "threshold number."

The results with the cold odor test, when using this method are very satisfactory indeed and the blindfold tests, as well as check tests by other observers, demonstrate that comparable results may nearly always be secured.

The hot odor tests are not so satisfactory, although it is generally true that this test gives figures equal to or lower than the cold test. It is considered that the cold odors should be used as the basis for "threshold number" determinations at Chester.

TABLE 1

Raw water

DATE (1934)	STANDARD METHOD	THRESHOLD NUMBER
Jan. 8	4. Oily	16 Oily
9	4. Oily	16 Oily
10	3. Oily	8 Oily
11	4. Oily	100 Oily
12	5. Oily	200 Oily
13	5. Oily	100 Oily
15	5. Oily	200 Oily
16	5. Oily	64 Oily
17	5. Oily	100 Oily
18	5. Oily	100 Oily
19	5. Oily	200 Oily
20	5. Oily	100 Oily
22	5. Oily	100 Oily
23	5. Oily	64 Oily
24	5. Oily	64 Oily
25	5. Oily	64 Oily
26	5. Oily	200 Oily
27	5. Oily	100 Oily
29	5. Oily	100 Oily
30	5. Oily	64 Oily
31	5. Oily	200 Oily

Table 1 illustrates the comparison between the odor determinations made by Standard Methods and the dilution method, also showing the dilutions used and how clearly the dilution method indicates what is going on in the river.

It will be noticed that up to 64 we use Professor Fair's dilutions, but above this point we feel that it is possible to detect odors in steps of 100. However, more work with the high intensity odors will have to be done before reaching a definite conclusion.

(*Presented before the 4-States Section meeting, March 7, 1934.*)

BREAK IN SUPPLY MAIN BRINGS PERMANENT IMPROVEMENT IN THE QUALITY OF WATER

By M. H. Coblentz

(Senior Assistant Sanitary Engineer, State Department of Health, Baltimore, Md.)

In spite of the rapid advancement in the treatment of water supplies for domestic and industrial use the consumer is frequently justified in criticizing the quality of water delivered. The reason is obvious. Control and maintenance of the distribution system which is an integral part of water supply has been almost universally neglected. Within recent years the practice of correcting aggressive waters is notable. Had the recent drought not developed the chlorine-ammonia treatment, the means of maintaining chlorine residuals in remote sections of water supply distribution systems would probably not have been at hand. Present thought is concentrated on the development of protective coatings for the existing metal distribution system and possibilities of material that is noncorrosive. Such trends unfortunately retard the more vital studies of this phase of water supply. Regardless of the type of distributing mains the delivery of satisfactory water to every consumer is not possible unless there is proper control of the distribution system.

The dead end and low draft sections of any system develop difficulties with water regardless of its character. A clear understanding of the behavior of water organisms in distributing mains and the chemistry of chemically treated water suggests that mere lime correction of aggressive water and chlorination are not sufficient. Water held in distributing mains beyond certain limits deteriorates regardless of its original quality. Water ionizes very little. The methods of treatment, however, to which most supplied are subjected, increases this process tremendously and when it is put into a carrying system of metal you cannot expect to receive the same water at the tap as you deliver from the treatment works.

An experience at Annapolis and Eastport, Maryland, illustrates the result of neglect of the delivery equipment in a water supply system.

Annapolis, Maryland, prior to 1931, had an untreated water supply

from a swampy area run-off. The supply was chlorinated. The consumers were accustomed to intermittent turbid and ill tasting water. In 1931 a filtration plant was installed and clear, sparking, non-corrosive water was delivered. At that time the water company was advised to clean the mains. This was not done. After two years the 2 mile force main was cleaned and the standpipe was cut

TABLE 1

Results of corrosion survey of Annapolis and Eastport distribution systems on January 23, 1933

STATION			TEMPERATURE, °C.	DISSOLVED OXYGEN		PARTS PER MILLION				pH	REMARKS
Number	Location	Tap		P.p.m.	Percent saturation	CO_2	Iron	Caustic alkalinity	Total alkalinity		
	Eastport										
1	Mr. Smith, Parkwood Ave.	Cold	20	0.60	6.54	0	2.2	2	24	8.5	Dead end. Galvanized steel plumbing
		Hot	28	0.48	6.06	0	1.6	2	20	8.5	
	Eastport										
2	Mr. Corner, 588 Eastern Ave.	Cold	9	1.30	11.21	0	5.0	2	16	8.5	Near dead end. Galvanized iron plumbing
		Hot	35	0.84	11.94	0	6.0	2	18	8.5	
	Eastport										
3	Collimore Store, 3rd & Severn Ave	Cold	11	11.08	100.00	0	0.6	1	18	8.6	Near dead end. Galvanized steel plumbing
		Hot	35	5.00	71.12	1	5.0	0	16	8.5	
	Annapolis										
4	Mr. Caspari, 42 Linden Ave.	Cold	12	11.30	104.34	0	0.4	0	16	8.6	Looped mains. Galvanized steel plumbing
		Hot	35	7.90	112.37	0	1.4	1	18	8.7	
Filter house	Service pump	—	9	12.40	106.98	0	0.005	0	12	8.5	Leaving filter plant

Note: Water generally discolored in Eastport. Water generally clear in Annapolis.
14-inch force main at Camp Parole repaired after break on January 9, 1933.

out for painting. The direct pumping on the system caused a break in the supply main and the hydraulic disturbance precipitated trouble. The State Department of Health was called in to investigate the sudden appearance of muddy water at practically all points on the system. The treatment of the water was immediately criticized. A corrosion survey was made and the results clearly showed that the hydraulic disturbance had stirred up the accumulation of corrosion

products in the distributing system. The water leaving the treatment works was clear, sparkling and free from iron.

Following the investigation, which clearly demonstrated the cause

TABLE 2

Results of corrosion survey of Annapolis and Eastport distribution system on January 27, 1933

STATION	TEMPERATURE, °C.	DISSOLVED OXYGEN		pH	PHENOLPHTHALEIN ALKALINITY, P.P.M.	TOTAL ALKALINITY, P.P.M.	IRON, P.P.M.		
		P.p.m.	Percent saturation				Ferrous	Ferric	Total
Eastport									
1	15	0.60	5.91	4.8	0.0	6	0.0	2.0	2.0
2	11	4.26	38.44	7.0	0.0	14	0.0	6.0	6.0
3	11	10.20	92.05	7.4	2.0	14	0.0	0.6	0.6
4	13	7.32	69.05	7.4	4.0	12	0.0	1.7	1.7
5	8	10.08	84.92	6.9	0.0	14	0.0	16.0	16.0
6	8	7.68	64.70	6.9	0.0	12	0.0	17.6	17.6
7	6	0.36	2.88	7.5	2.0	16	0.0	3.4	3.4
8	7	0.96	7.88	6.6	1.0	14	0.0	10.0	10.0
9	8	4.08	34.37	7.5	0.0	14	0.0	12.8	12.8
Annapolis									
10	10	9.48	83.67	7.5	0.0	12	0.0	0.8	0.8
11	11	9.00	81.22	7.5	0.0	12	0.0	1.7	1.7
12	13	10.20	96.22	7.6	0.0	14	0.0	0.9	0.9
14	7	9.72	80.00	6.8	1.0	14	0.0	8.0	8.0
15	7	10.92	90.00	7.5	0.0	12	0.0	3.0	3.0
16	7	9.72	80.00	6.8	1.0	18	0.0	80.0	80.0
17	8	13.92*	117.27	6.6	1.0	14	0.0	12.0	12.0
18	7	8.28	68.00	6.9	2.0	18	0.0	50.0	50.0
Force Main									
19	5	10.80	84.37	6.9	1.0	14	0.0	18.0	18.0
Service Pump									
20	6	10.92	87.50	8.3	3.0	19	†	†	†

* Plug valve opened quickly. Water running brown to black after 15 minutes. Result hardly representative.

† Sample lost—broken container.

of the trouble, it was learned that there was a haphazard system of flushing of the distribution system. To make distribution system blow-off effective side mains must be cut off before fire hydrants are

opened. Otherwise there is a stirring up of stagnant water in the section of the main and there is no clean-out.

Annapolis' experience should be helpful in the following directions:

1. To remove iron and manganese and otherwise produce a clear sparkling water is not sufficient.

2. The water leaving the treatment works is not what the consumer gets.

3. The distribution system must be properly operated. The practice of opening fire plugs without some regard for the grid tie-in often defeats the purpose of the work.

TABLE 3

Contents of iron at the high lift pump in filter house

(Results in parts per million)

DATE	IRON	pH
2-24-31	0.2	7.4
2-27-31	0.0	7.5
1-26-32	0.0	6.9
4- 5-32	0.0	7.2
5-12-32	0.0	7.3
1- 9-33	0.0	7.0
1-20-33	0.0	8.8
1-23-33	0.005	—

4. No community should plan improvements in water supply unless the wreck of the old supply is removed. Some of the analytical results in tables 1, 2 and 3 show the character of the water which consumers had to tolerate during the hydraulic disturbance.

The expensive break in the supply main has apparently benefited the consumers. Annapolis has established a systematic, properly operated control of main flushing designed to clear the system and to deliver water of the quality produced at the treatment works.

(*Presented before the 4-States Section meeting, March, 7, 1934.*)

EARTHQUAKE EFFECTS ON WATER SUPPLIES

LONG BEACH

By Fred S. Porter

(General Manager, Water Department, Long Beach, Calif.)

A résumé of the damages done to the Long Beach water system as a result of the earthquake which occurred March 10, 1933, and a brief description of the general lay-out of our system will materially assist in visualizing the extent of these damages.

The average daily consumption of the City of Long Beach is approximately 18 million gallons per day. The 1930 census gave the population of our city as 142,030. The average daily consumption is 128 gallons per capita.

The Long Beach water supply is derived from gravel beds from 200 to 1700 feet beneath the surface of the Coastal Plain or valley lying within and to the north of the city. Water is produced from 33 wells ranging from 200 to 1668 feet in depth and from 10 to 16 inches in diameter. The first 250 feet of 21 of our wells have 26-inch diameter casing to allow the installation of large deep well turbine pumps.

Twenty-five wells are now equipped with deep well turbine pumps; seven are equipped for pumping by air, and one is not equipped at present. Seven turbine equipped wells pump directly into the distribution system and the other eighteen turbine equipped wells pump into concrete collecting cisterns at our two booster pumping stations.

The Citizens booster pumping station is equipped with six 10-inch two-stage centrifugal pumps having a total pumping capacity of 15,600 G.P.M. At this plant there are two concrete collection cisterns with a capacity of 600,000 gallons and 3,500,000 gallons.

The Alamitos booster pumping station is equipped with three single-stage centrifugal pumps with a total capacity of 8,200 G.P.M. This plant has a concrete collection cistern having a capacity of 2,600,000 gallons.

The Citizens and Alamitos plants are at an elevation of 38.00 and 28.00 feet, respectively, above sea level. The water is pumped from them through one 24-inch and two 30-inch cast iron transmission mains to the Alamitos storage reservoir, the top of which is 205 feet above sea level.

The storage reservoir consists of six steel tanks, each 132 feet in diameter and 35 feet in height and having a capacity of 3,450,000 gallons, or a total of 20,700,000 gallons.

The collection, transmission and distribution systems consist of the following amounts of pipe:

	COLLECTION		TRANSMISSION		DISTRIBUTION	
	Inches	Miles	Inches	Miles	Inches	Miles
Cast Iron	12–30	3.2	12–30	3.1	2–30	367.5
Concrete	16–42	6.8				
Steel					2–16	21.8
Total		10.0		3.1		389.3

Grand total 402.4 miles.

The distribution system contains 28,052 active services constructed of lead, steel, wrought iron, copper and cast iron pipe. The use of cast iron has been adopted for all street services, each consisting of a two-inch lateral running from the main to a tee inside the curb and serving two or more lots. To date 10,454 of these laterals have been constructed.

The effects of the earthquake on the various parts of the Water Department property will now be taken up in detail.

EFFECTS ON STEEL TANKS AND CISTERNS

An inspection of the steel storage tanks twenty minutes after the shock showed that they were in perfect operating condition. Later inspection showed that the roofs had been slightly damaged, and a subsequent survey showed a slight settlement of a portion of one of the tanks. At the time of the shock, the tanks contained 20 feet of water, or approximately 12,000,000 gallons.

The cistern at the Alamitos Plant was under construction, but sustained no damage. The new 3.5 million gallon concrete cistern recently completed at the Citizens Plant was full of water at the time

of the 'quake. No damage was done to the portion constructed of reinforced concrete, and only slight damage was done to the wooden roof. An inspection of the ground near the walls showed that the structure had received a heavy shock.

EFFECTS ON PUMPING EQUIPMENT

No damage was done to any of the booster pump foundations, pumps, pipe connections or electrical switches. At the Citizens Pumping Plant a portion of the brick wall fell and damaged the bus bars at the transformer and it required about two and a half hours to make this repair.

TABLE 1

SIZE	MILES OF PIPE	NUMBER OF BREAKS	NUMBER PER MILE
inches			
2	6.6	4	1 to 1.66 miles
4	32.8	4	1 to 8.20 miles
6	151.1	80	1 to 1.87 miles
8	87.7	18	1 to 4.87 miles
10	8.0	2	1 to 4.02 miles
12	51.2	21	1 to 2.44 miles
14	1.7	None	None
16	1.3	None	None
18	0.5	None	None
20	18.4	1	1 to 18.44 miles
24	2.3	None	None
30	5.9	None	None
Total.....	367.5	130	

The power line to the Alamitos Pumping Plant was broken, with the result that the plant was out of service for about eight hours.

No damage was done to the pumping, electrical equipment or pipe connections at the wells; but at some well locations movement was so great that most of the oil was thrown out the tanks of the oil switches. Movement was also indicated at each of the wells by the shifting of the heavy transformers on their foundations, and cracks in the concrete floors of the pump houses.

EFFECT ON REINFORCED CONCRETE MAINS

The reinforced concrete collection mains constructed during the last two years to convey water from the newly developed water bear-

ing lands northeast of the city to the Booster Plants, withstood the shock in a satisfactory manner. There are 4.8 miles of pipe in these mains, 24, 30 and 42 inches in size, designed for a 50 foot head. The soil in which they were laid is naturally deposited silt, the ground water level being well below the bottom of the trench at the time of construction. The damage to these mains consisted of a 30-inch hub gate valve broken by the terrific compressive force which required its removal from the line; broken pipe and joints of 24-inch pipe which required replacement; the shearing off of a 30-inch pipe where the main joined a concrete cistern; broken pipe and joints of 42-inch pipe where the main joined a concrete cistern, and one 42-inch joint where steel and concrete pipes were joined.

The breaks in all the above cases, except the 30-inch gate valve, were caused by the lack of flexibility between the pipe and fixed structures. The breaks in the 24-inch reinforced concrete pipe were between a bend around which a large block of concrete was poured, and a brick man-hole. Eighty feet of this 24-inch pipe was relaid with flexible joints. The 30- and 42-inch connections between the pipe line and the concrete cisterns were relaid with a flexible steel expansion joint. The failures as indicated above did not require the mains to be put out of service immediately after the 'quake.

The 30-inch line was used for 48 hours before it was shut down, and the 24-inch line was used eight days before the first leak developed to an extent which made it necessary to take the line out of service. The leaks in the 42-inch pipe were small to start with and the mains were used several days before the repairs were made.

It is difficult to determine just what damage was done by the first heavy shocks, but it must be borne in mind that many subsequent shocks occurred which caused breaks to develop at points weakened by the first and most severe shock.

EFFECT ON DISTRIBUTION SYSTEM

Cast iron mains. As stated earlier in this paper, the system contains 367.5 miles of cast iron mains ranging in sizes from 2- to 30-inch. A survey shows that 130 breaks occurred in mains. The number of breaks and the number of miles of pipe, by sizes, in the system are shown in table 1.

An analysis of the location of the breaks shows that 52 percent of them occurred in the southeast area of the city where the land has been built up by a dredged fill on tide flats; 38 percent occurred in

sections where the soil is of a naturally deposited silt with the ground water near the surface; and 10 percent occurred in hard adobe soil.

It will also be noted that the breaks are in sizes from 2 to 12 inches, with one pulled joint in a 20-inch main. Approximately 28 percent of our 20-inch pipe is laid in silty soil.

In the Alamitos Bay Peninsula district forty-five 2-inch and fifteen 4-inch separations occurred. They were caused by a north and south elongation of the streets. Surveys showed movements of 1.84 feet in 450 feet; 4.0 feet in 700 feet and 5.0 feet in 370 feet.

Steel mains. The system contains 21.8 miles of steel pipe in sizes of 2 to 16 inches in which 135 breaks occurred. All of these breaks were in one district where the pipe had reached a condition where replacement was already necessary.

Services. A survey of our 10,454 cast iron service laterals showed that only two breaks occurred in them between the main and the tee at the curb. All other breaks in cast iron services were either brass nipples or malleable fittings at the tee. A total number of 85 service breaks occurred in the entire system, 10 of which were in silty soil in North Long Beach and 75 in the Belmont Shore-Naples area where the soil is dredge-filled on tide flats.

Breaks, probably numbering into the hundred, occurred in the service pipe on private property beyond the meter due to houses and buildings moving on their foundations, but these have not been considered in this paper as we have no record of them and are not responsible for their repair.

EFFECT OF BOOSTER PUMP HOUSES

The buildings housing the booster pumps at both the Citizens and Alamitos pumping stations were constructed of brick, with walls 15 inches thick and wood trusses and corrugated steel roofs. The walls of these two buildings, together with two storage buildings at the Citizens Plant, were so badly damaged that it was necessary to demolish them. At the Alamitos Plant new walls of wood and corrugated steel were built under the old roof to replace those of brick. At the Citizens Plant the entire building was demolished and a new steel frame building covered with Robertson protected metal walls and roof was constructed.

EFFECT ON WELL PUMP HOUSES

The buildings housing the pumps at the individual wells are of two types; wooden frame covered with corrugated steel, and brick

construction. The former suffered no damage, but some of the brick buildings required rebuilding. Two types of construction have been used on the brick buildings. All of the brick pump houses are 10 feet by 20 feet in size with concrete foundations and floors. The buildings constructed previous to the Santa Barbara earthquake of June 28, 1925, contained 9-inch brick walls plastered on the outside with cement stucco. These were so badly damaged that it was necessary to entirely replace several of them with new structures. Those constructed since that time have 9-inch brick walls with reinforced columns at the corners and a reinforced concrete bond beam around the top of the walls. The latter buildings suffered no damage from the 'quake.

EFFECTS AT MAIN SERVICE STORAGE PLANT

The damage at the main service storage plant was considerable, 1900 of the 2400 feet of fence surrounding this plant being destroyed. This fence was 7 feet high and 8 inches thick, constructed of concrete blocks plastered on one side.

The buildings were constructed of brick with a reinforced bond beam around the wall above the openings. The brick ends and intermediate fire walls, from the bond beam to the roof, were so badly damaged that it was necessary to replace them with reinforced concrete walls.

The crushed bricks at the top and bottom of the windows and column, also along cracks in the walls, were removed and the channels filled with gunite.

EFFECT ON PUMPING OPERATIONS

For a number of years our main booster plants and two groups of our wells have had two independent sources of power to assure uninterrupted service. When the first shock occurred March 10, 1933, at 5:55 P.M., the power to the entire system was cut off and was not resumed for from nineteen minutes to one hour and thirty minutes. Within the first 90 minutes following the first shock, seven wells with a total capacity of 7,000 G.P.M. were pumping directly into the distribution system. The main Citizens Booster Pumping Plant was out of service until 11:35 P.M., March 10th, and the Alamitos Booster Pumping Plant was out of service until 1:45 A.M., March 11th.

The draft on our storage due to main and service breaks and un-

usual demand for fire fighting use emptied five of the tanks by midnight with only eight feet of water left in the sixth. By this time resumption of pumping at the main booster plants halted further depletion, but it was 6:00 A.M., March 12, before all six tanks were entirely filled again.

CONCLUSION

From our experience, and that of many other cities in the zone affected by this earthquake, certain factors are necessary to any water system in a known earthquake area, to-wit:

1. Ample capacity and a safe type of water storage.
2. Properly housed pumping equipment.
3. Dependable source of power.
4. Reserve stock of each size of pipe for use in this type of emergency only. (Our reserve stock consists of 120 feet of each size.)
5. Dependable communication facilities.
6. Chlorinating equipment at the main pump stations and portable equipment for local disinfection of mains at time of repair.
7. A complete and accurate record showing location of all gate valves for immediate reference.
8. A personnel instructed where to report in case of a catastrophe of any kind.

AMERICAN STATES WATER SERVICE COMPANY

By C. P. Harnish

(*Civil Engineer, Los Angeles, Calif.*)

The American States Water Service Company of California supplies water to some 42,000 consumers in thirty communities in Southern California. About half of the territory served by the company lies within the area affected by the earthquake of March 10, 1933. The affected area can be generally described, with minor exceptions, as lying between the coast and a line drawn from Huntington Park to Santa Ana. In this affected area the company has fourteen separate water systems, the largest serving 6,000 consumers and the smallest, 70. Included in this group are the incorporated cities of Bell, Gardena and Huntington Beach, Green Meadows District within the City of Los Angeles, and unincorporated districts

of Florence-Graham near Huntington Park, Lawndale and Lennox near Inglewood, together with seven smaller districts in Los Angeles and Orange Counties.

Water service was adequately maintained at all times in the larger systems including all those named above. Elevated storage, power service from two different sources and some gas engine reserve units were factors which contributed toward the maintenance of service during this trying period.

Three of the smallest communities served by the company were particularly hard hit and did not fare so well as to water service. Los Alamitos in Orange County with 175 consumers had no water service from the time of the earthquake until the following morning. The elevated steel storage tank was damaged and the riser pipe had broken, letting out all of the water. The electric power service was also out, so that direct pumping into the mains could not be done until the following morning. Seventy consumers in the small community of Cypress nearby were without water for about six hours during interruption to power service. About 25 percent of the distribution system in the small community of Hollydale near South Gate in Los Angeles County, had to be cut out of service following the quake because of pipe line breaks, but service was resumed by noon of the following day. Thus about 300 out of the total of 21,000 consumers in the earthquake area were without water service during and immediately following the catastrophe.

During the succeeding days, a full and complete survey disclosed that none of the pumping plants of the company were damaged, neither the buildings nor the equipment therein. Most of these stations are small and of frame or frame and stucco construction.

Two sub-offices, one at the corner of Florence and Compton Avenue in the heart of a badly damaged area, and the other in Huntington Beach, had to be temporarily vacated. Both were one story brick buildings.

No damage was observed to any of the company's water wells, of which there were 35 within the area affected.

No concrete reservoirs were damaged to any appreciable extent.

There are seven elevated steel water tanks maintained by the company within this area and they all felt the affects of the quake to a greater or less degree. The structures are all of the standard hemispherical bottom type on steel towers approximately 100 feet high. In each of these tanks it was noticed that the diagonal tie rods

in the top panels had stretched and loosened. In four instances a careful survey disclosed this to be the only damage done. The elevated tank in Artesia, in addition to loose tie rods, had several small leaks in the tank bottom, the repair of which was of minor consequence. In the tank at Hollydale one of the tie rods was broken and several had been stretched to such a point that they had to be removed and shortened, following which the tank was put back into service and is apparently now as sound as the day it was erected.

The tank at Los Alamitos was the most severely damaged and it is apparent that had not the riser pipe broken, letting out the water quickly, the tank would have collapsed. All of the tie rods in the upper panel were badly stretched or broken either in the rod itself or at the support to the tower. This was a four column tower and the connections between the tops of two of the columns and the tank were badly bent. It was found possible to remove the top sections of these damaged columns, one at a time, have them straightened and repaired and put back in place. New and larger tie rods were put in the top panel and the columns were carefully realigned. This structure is believed now to be in better shape than when it was first erected, and the cost of repairs has been within $500.00.

The most serious difficulty was with pipe line leaks. The company has approximately 365 miles of pipe lines within this area, and there were a total of 247 leaks repaired which were chargeable to the earthquake. About 25 percent of the total mileage of pipe is cast iron and not over four leaks occurred in this class of pipe, the balance occurring in steel mains of which a considerable proportion are of riveted steel pipe with slip joints. On an average there was one leak to every 1½ miles of pipe, with a maximum running as high as one leak to every 0.2 of a mile in Los Alamitos, which community was badly shaken up.

The leaks in the steel mains were of many varieties. Many minor leaks were due to the usual run of rust spots or pit holes which would have broken out sooner or later anyway, but which were sprung all at once after the severe shake-up which they experienced. In the riveted steel pipe there were numerous split longitudinal seams, as well as sheared rivet heads.

The small system of Hollydale near South Gate probably suffered more than any other. In one area three blocks wide there were 24 leaks in which the mains were either pulled apart or telescoped, in some instances as much as 6 inches. In one location the main had first telescoped and then backed away nearly 6 inches. These mains were of lap weld steel pipe with welded field joints.

Only one serious break occurred in large pipe and this was in a 14-inch transmission line of steel pipe weighing 30.2 pounds to the foot at Huntington Beach. This line was broken cleanly through a field weld and the pipe was pulled apart about 6 inches, one end being also about 6 inches above the other. Inspection showed the weld to be of very good workmanship and it is a coincidence that three steel oil lines, running parallel to the water main, had broken at exactly the same point. Incidentally the repair man nearly lost a couple of fingers when repairing this break as another quake drove the two ends of the pipe sharply together and then back again. This break at Huntington Beach was of such a character that it could not be repaired until the following day, but no water shortage resulted since there is considerable reservoir storage available, and (fortunately) a reserve pumping plant discharging to the reservoir through a separate pipe line.

A number of leaks occurred in service connections, mostly at the corporation cocks. The number of leaks in service connections was, however, somewhat less than those in the mains and in all cases occurred where connections were made up of steel pipe without flexible goosenecks.

Probably few new lessons can be learned from the earthquake, at least in the waterworks field. Rather, this castrophe has served to impress upon those of us who experienced it, the importance of the old fundamentals which we may have been inclined to lose sight of during periods of rapid expansion. Diversification in water supply facilities with duplication of all important units, a strong gridiron distribution system, well gated, are all fundamentals which we have been taught to believe in, but the force of which now we realize to a greater degree than ever.

It is clear that any structure erected in California must be designed to withstand earthquake stress. Elevated steel tanks are particularly conspicuous and it is natural that some apprehension would exist among those living or working near such structures. By and large they came through the earthquake in good shape, but it is believed from the experience of the American States Water Service Company in this earthquake that certain additional provision should be incorporated in the design of such structures to withstand earthquake stress over and above those heretofore considered adequate, and, further, that existing tanks located adjacent to other buildings be reinforced along the lines indicated. In the great majority of cases, the expense should be nominal.

LYNWOOD

By A. J. Bateman

(*City Engineer and Water Superintendent, Lynwood, Calif.*)

The damage as a direct result of the earthquake of March 10, to water lines and other water works structures was somewhat less than might have been expected considering the intensity of the shock and general condition of the system. The entire piping system consists of approximately 45 miles of mains of which approximately 30 percent is cast iron, 15 percent wood stave and 55 percent riveted steel. Except for the brief interval during which there was no power, water service was uninterrupted, although pressure in certain sections for a time was as low as 12 pounds, due to large breaks and if a serious fire had resulted from the shock a large property loss would have probably resulted in these areas. In all some 150 leaks and breaks were repaired. All of the larger breaks were repaired within a period of three days, although many of the smaller breaks were not fully repaired for approximately three weeks. As many of these lines were over twenty years old, of light gauge pipe and consequently near the end of their expected useful life, the resultant damage and interruption to service was to be expected.

Of the 14 miles of cast iron piping there was no damage with the exception of two small leaks at joints which were no doubt caused through faulty caulking at the time the lines were originally laid. All other breaks occurred in the older wood stave and riveted steel lines, one 8-inch wood line under a concrete pavement being necessarily abandoned and paralleled by a new cast iron pipe line laid in the parkway.

Of the other water works structures, the only damage suffered was to two of the department's three elevated storage tanks, one of which was entirely demolished. The tank which collapsed was full of water at the time of the shake and witnesses describe it as doing a weird sort of dance step for several seconds followed by the failure of the south legs. A woman who was watering her lawn about fifty yards away was reported as suffering from a fractured leg when thrown against a fence by the escaping water. This tank was of 25,000 gallon capacity and its failure was probably due to faulty design of connection details and inadequacy of tie rods as all vertical members and foundations were amply designed. This tank has since been replaced by a 100,000 gallon tank designed in accordance with the

standards of the National Board of Fire Underwriters for earthquake resisting structures. The other tank damaged, of even smaller capacity, was only partially filled with water and while it did not collapse, all tie rods in all three panels were broken and the tower was leaning to the north about 13 inches at the top. These rods were immediately replaced with larger rods, the tower plumbed, and the unit again placed into active service.

There was no damage whatsoever to either pumping equipment or wells. While in some localities a slight raising of water levels was reported, there was no such effect noted in any of the water department's five wells.

Due to the many breaks and possibility of contamination from adjacent cess pools and sewer lines it was deemed advisable to chlorinate all water pumped for a period of 10 days. This service was rendered promptly and efficiently through portable chlorinators furnished and installed at no expense to the city by the Los Angeles County Health Department with the coöperation of the Wallace Tiernan Company.

Taking all factors into consideration this department considers itself very fortunate to have escaped with so small a loss.

THE DOMINGUEZ WATER COMPANY

By E. P. Tallon

(Superintendent of Water, Dominguez, Calif.)

The Dominguez Water Company serves an area of about twenty square miles extending from the north boundary of Wilmington to the south boundary of Compton, and from the Los Angeles river bed on the east to the east limits of the city of Redondo on the west. There are about ten thousand people living and working in this territory, which includes several heavily populated subdivisions, and the city of Torrance. Water is supplied extensively for industrial, farming, truck gardening and dairy purposes, as well as for domestic use.

Eleven of our twelve wells are located within a radius of one half mile from our main pumping station at Alameda and Carson Sts., near the east limits of our territory. Five of these wells are pumped by air from our main steam plant, and six by electric driven deep well turbines. These eleven wells feed into a sand settling basin adjoining our main plant. The water then flows down an aerating ramp into the collecting sump, where it is chemically treated with chlorine and

ammonia and from which it is led to the pump intake pipes by means of a concreted tunnel five feet high by four feet wide.

Within the building are two 300 h.p. Sterling boilers operating at 150 pounds steam pressure; two Laidlaw-Dunn-Gordon steam driven air compressors; one 4 m.g.d. Prescott steam pump, and one 8 m.g.d. pump; and a DeLaval steam turbine unit with twin centrifugal pumps having a capacity of 3,000 g.p.m.; in addition to miscellaneous auxiliary equipment. This steam equipment represents about half the pumping capacity of the plant. The electrical equipment consists of two Worthington centrifugal pumps driven by 125 h.p. G. E. motors and pumping 4,000 g.p.m. against a 99 feet static head; and one two stage Worthington centrifugal pump driven by a 150 h.p. G. E. motor, and pumping about 1,400 g.p.m. against a 207 feet head.

From the pumping station two mains extend to two relatively small reservoirs, both of the earth embankment type. The Number 1 reservoir is located about eight miles west of the main plant; is served by a 33-inch main, and has a capacity of fourteen million gallons, with a static head of 99 feet. Number 2 reservoir is located on Dominguez hill, about three miles northwest of the pumping station. It is served by a 20-inch main, against a 207 feet static head, and has a capacity of seven million gallons. Number 1 reservoir supplies most of the system including the city of Torrance, while Number 2 supplies farmers and industrial users on the hill itself. Extending from these reservoirs are about 75 miles of pipe line, 22 miles of which are wire wrapped redwood pipe, and the remainder riveted steel pipe, most of which has been concreted.

When the March 10 earthquake hit us at the Dominguez Water Works it looked for a short while as though our entire system had been shaken to pieces. Our main engine house was virtually demolished; the engineer and oiler barely escaping with their lives. Main steam lines were completely torn apart and the steam escaped into the wreck of the building. The resulting muck and débris under which all the machinery was buried made the pumping plant look like a total loss. The settling basin, collecting sump, and water feed tunnel adjoining the engine house all were severely damaged. Pressure in both main lines dropped badly immediately after the first shock of the quake, and the rapidly falling water level of our two reservoirs gave our men a scare until they were able to get the main valves closed and found that the reservoirs themselves were undamaged. In spite of all this evidence of damage to our system the service to

ninety per cent of our consumers was virtually uninterrupted, and no portion of the system was without water for more than twenty four hours.

Since the earthquake we have learned that our main plant is located directly over the Inglewood fault to which this quake is attributed. Also, we have since found that we are near the center of the area that was hardest hit. Brick buildings within a block or two of our plant were completely shaken down, and the very heavily built Pacific Electric sub-station, just two miles north of us at Dominguez Junction, was utterly demolished, killing the operator. So we feel that we were getting our share of the shaking.

It is of interest, too, that sub-soil conditions in our territory are unusually bad as regards earthquakes—consisting of deep deposits of sand and quicksand, water saturated. As a result of this the surface of the ground reacts to a quake like a bowl of jelly to a violent shake. The motion is exaggerated into a heavy rolling movement of exceptionally destructive character, especially to imbedded pipe lines.

Serious damage was suffered by the oil pipe lines, gas mains and water systems in or near our territory, service being delayed several days in some cases. Gravity storage tanks suffered heavily, also, one steel water tower crashing to the ground, and many being so severely strained that it was necessary to drain them until repairs could be made.

We can credit much of our own success in meeting earthquake conditions to the fact that we have developed our system in every possible way to meet emergencies that we could not forsee. We pump about half of our wells by air and half by electricity. The capacity of our main pumping plant is about evenly divided between steam and electricity, and we have a small independent pumping station as well, run by electricity and located eight miles away from the main plant. We have two different systems of mains and two independent reservoirs to meet conditions in different parts of our territory. So we do not expect any emergency to put us entirely out, even temporarily.

Our main pump house was of unreinforced concrete construction with walls 12 inches thick. The building was 22 feet high, 55 feet wide and 110 feet long. The south wall was completely shattered, falling inward into the plant and doing considerable damage to miscellaneous equipment. The remaining walls were badly broken and would have fallen if the north wall had not been braced by an adjoining steel surge tank.

Within the building the damage to the steam lines at once placed all steam equipment out of commission, cutting our maximum pumping capacity in half. Our auxiliary pumping station at Number 1 reservoir, about eight miles west, was undamaged and continued pumping at the rate of 2,000,000 gallons per day. This independent pumping station, with its own electrically pumped well, clearly demonstrated the value of such an installation in time of emergency. We must also give credit to the Southern California Edison Company for maintaining the power on their lines which made it possible for us to use our electrical equipment.

At our main plant we found that all six of our electrically pumped wells were undamaged, and in spite of the damage to our collecting sump and feed tunnel we were able to supply our electric pumps with water. While the wreck of the building was still shaking with the recurring after-shocks our men were able to dig No. 6, an electrically driven two stage Worthington centrifugal unit, out from under the débris and get it into operation.

In the meantime we located the breaks in our mains and went to work on them. While repairing these breaks we supplied consumers from the reservoirs and our auxiliary pumping station. The town of Dominguez itself was supplied, until we got No. 6 pump in action, by an emergency hook-up with a portable gasoline engine pump.

Our pipe lines stood the quake remarkably well. We have 22 miles of wood pipe, which was not damaged at all. In addition to this we have some 45 miles of riveted steel pipe, most of which has been protected by concreting, and this suffered very little. We had a total of seven breaks in our concreted pipe, five of which came within a distance of 150 feet, and only two of which were really serious. The bad breaks occurred at a spot about one mile west of our main plant, at the intersection of Wilmington and Carson Aves. There was every indication that the earth shocks were exceedingly severe at that particular point. The concrete road bed of Wilmington Ave. was badly broken along east-west, as well as north-south lines, and several slabs were moved vertically. The condition of the highway, of our own lines, and of a crude oil line of the Shell Oil Company, all damaged at this same spot, indicated that the earth had suffered a terrific grinding movement, although there was no evidence of a fault line.

Since our method of concreting pipe is unusual we feel gratified with the way these lines withstood the quake, proving the effectiveness of this method of pipe line repair and replacement. Our method of

concreting pipe without interrupting service has proved economical, and the life of the concrete pipe so placed has been found to be far in excess of that of the steel pipe which it supplements.

It took us about forty-eight hours to repair the earthquake breaks, by removing the concrete, welding on steel plates, and re-concreting.

At our main plant we found all of the electrically driven pumps undamaged and it did not take us long to get the walls of the building braced so that we could operate without bringing the rest of the building down around our ears. Of course, the electric pumps alone could not handle our maximum load, which comes during the early summer, so it became a race against time to get our steam plant back on the line before the capacity of our electric equipment was exceeded. On May 9, just one day less than two months after the earthquake, we were able to place our steam equipment on the line. This was before the building contractor had completed the foundations for our new pump house.

While the old building was being wrecked and the new one constructed we had some trouble with sand and water getting in the electric motors, and other minor problems due to the confusion of operating in the midst of a mass of scaffolding and building materials. But we did not permit this to hamper our service, and were able to repair our damaged weir, sump, and feed tunnel without any inconvenience to our consumers.

We have refitted our plant, and repaired our system so thoroughly, and now have such a solidly built engine house, that we feel we can face any future earthquakes without fear of major damage, even if we are sitting on top of the main Inglewood fault.

(Presented before the California Section meeting, October 26, 1933.)

SOUTH GATE

By L. M. Rothkranz

(Superintendent, Water Works, South Gate, Calif.)

The City of South Gate has a population of about 21,500 inhabitants, and spreads over an area of seven square miles.

Our water system is composed of 16, 12, 10, 8, 6 and 4 inch mains of cast iron, wood and steel. We have eight turbine pumps in operation with capacities of from 500 to 1200 gallons per minute, and before the earthquake castrophe, we had two 150,000 gallon steel elevated tanks,

with heights of 150 and 165 feet to top, above ground surface. They were about two and a half miles apart and used principally as surge tanks. All the pumps are pumping direct into the main and are controlled by hand as well as automatic pressure switches. Services are 100 percent metered. The system carries a constant pressure of 55 to 60 pounds. All the mains are tied together in one unit.

At about six o'clock in the evening of March 10, I was standing in my back yard when the earthquake started. It was so strong that I had to spread my feet apart and brace myself to keep my balance. It amused me to see my house doing a regular Black Bottom dance. I heard a loud crash, and looking quickly in the direction of one of our elevated tanks located about three blocks away, I saw that the tank was gone, and already the gage at the house stood at 30 pounds pressure.

Jumping into my car, in which I always carry emergency tools such as main gate and other wrenches, I rushed to the location of the tank and closed two 12-inch gate valves in the street, as it was impossible to get any where near the tank site. Five automatically controlled pumps had cut in and were surely doing their best to flood this location.

I then went to the Police Department office, where the telephone switchboard for the City is operated. Two of my men arrived while I was taking down the locations of water line breaks which were being called in. In a very short time, we had made the necessary shut-offs, and were busy making repairs. We worked all night, in the early morning taking off four hours for a little sleep, before starting a long day's work.

During this time, only three families were without water for about six hours.

About four hours after the big quake, I carefully examined our other tank and tower, and found it was out of plumb about 12 to 18 inches. I set the float switch so it would only fill about one fourth full, and connected up a 3-inch steam boiler pop valve which I had in stock with a length of 2½-inch fire hose to a fire hydrant, never knowing whether this tank would stay up or not. The valve I set at 50 pounds blow-off.

The next morning I called up the Chicago Bridge and Iron Works and asked for an engineer to examine this tank. I was instructed to get the water out of this tank so that workmen could start making the necessary repairs by noon.

Some of the 1¼-inch square tie rods had stretched over four inches and the turnbuckles and eye stubs had partly broken loose from the rods in about twelve different places. I had no storage capacity but my old pop valve did the trick. We lost a little water by its use, but our pressure was enough for fire protection, as well as to supply the consumers for three days while the tank was being repaired.

At no time during this period following the earthquake did the pressure drop below 25 pounds, except for about ten minutes when the tank collapsed.

All the service pipes leading from the mains to the curbs are of annealed copper tubing ¾- or 1-inch in diameter, which saved us having to make new service connections, as there were no breakages here.

COLLAPSE OF 150,000 GALLON WATER TANK

The foundation pier on the northwest corner lowered three and one half inches. Eleven feet north from the bottom of this foundation pier we have a 12-inch well, 680 feet deep, which at one time was equipped with a single stage centrifugal pump used for irrigating. The pump was set into a 6-foot diameter circular concrete pit 26 feet deep, with 6-inch concrete wall. This pump was replaced eight years ago by a seven stage 11¼-inch bowls 8-inch column Turbine Pump. The well casing extended to the top of the surface and the pit filled with sand. Shortly after the quake, we started to pull this pump, but could not get the bowls out of the hole. We dug down to the bottom of the old pit and found the well had offset about four inches at and below the floor of the pit. The sinking of the tank foundation pier might have offset this well. After doing a lot of figuring as to weights and pressures, I changed my opinion and lay the cause of offsetting to the solid twenty-six foot filled pit which did not move as fast as the lower part during the quake movement which was eight feet north then back five feet south. I always wondered what became of the three missing feet.

I came to this conclusion through the examination of our sewer system. Mostly, all of our sewer breaks occurred on both sides joining manholes and house connections. It is now my belief that there was either a soft or hollow spot under this pier, or the construction was faulty.

When this tank came down, the force of the water was so great that it washed out about fifty feet of curb in the street, and carried these large blocks of concrete ten feet from the original location. A garage

located fifty feet from the tank and in which a Pontiac Sedan was stored, was carried thirty feet, the only damage to the car being to the hub caps on one side.

TANK NUMBER 2, 150,000 GALLON CAPACITY

I would suggest that heavier tie rods be used and better welding be done on the stub ends of turnbuckles.

The foundation of this tank consists of thirty two 30 foot steel reinforced concrete piling, eight under each leg, all tied together with reinforcing steel and concrete. This job was done by the Raymond Concrete Pile Company, and the foundation is as good now as it was the day it was built—even better, as it is well cured.

PRECAULKED CAST IRON PIPE

We had many leaks and breaks in these mains, caused by the pipe pulling out of the bells in many places.

WOOD STAVE PIPE

We have about 67,000 feet of wooden mains to look after, and I was very much surprised how well these pipes stood up. About twenty breaks showed up, caused by the corrosion of the wrapping wires through the action of alkali and the shaking of the ground. Even in places where the ground was badly cracked from the quake, these wooden lines must have moved with the quake like a rubber hose, as we found no bad leaks. We make all repairs to these lines by taking out a full length and replacing same with cast iron sleeves and cast iron pipe.

CAST IRON WATER MAINS; PORTLAND CEMENT JOINTS

Out of about one hundred and fifty miles of C.I. pipe, A. W. W. specifications, we had only one bell break, which was caused by the ground giving a sharp unheaval. It broke and raised the curbs, sidewalks and paving about three inches on each side of this break. I highly recommended Portland cement joints for cast iron water main construction.

On the day after the earthquake and periodically for about three weeks afterwards, the Los Angeles County Health Department made tests of samples taken from each of our wells and also from house taps and fire hydrants throughout the system, without finding a single case of contamination in our city water.

EFFECTIVE UTILIZATION OF THE PUBLIC WATER SUPPLY IN FIRE FIGHTING

By W. C. Mabee

(Chief Engineer, Indianapolis Water Company, Indianapolis, Ind.)

A recent editorial in one of our leading newspapers wrote of the effectiveness of the fire department in reducing fire losses, but made no mention of the excellent water supply facilities which made possible such valuable service and protection.

Of course, the fire department should be given full credit for its prompt and effective work in holding fire losses to a minimum; with equal justification however, credit should go to the water department for making this achievement possible.

The part played in the extinguishment of fires by the water department is all too often overlooked and generally goes unnoticed; yet a little contemplation of the subject will convince you that after all you cannot accomplish much in fire extinguishment without water and plenty of it.

Just as an army without ammunition is helpless, so a fire department without adequate water supply is likewise helpless. Water is the ammunition with which all fires of consequence are fought, and in the proper utilization of that ammunition depends our fire fighting effectiveness. Fire Chiefs understand this but the public at large apparently fails to appreciate the full value of the water supply in fire emergencies. There is no glamour connected with it; no clanging of bells nor shrieking of sirens heralding the arrival of the ammunition at the scene, for it is already there waiting for the apparatus and the firemen to arrive. When, however, a fire occurs beyond the limits of the water mains, and results in a total loss, attention is forcefully drawn to the situation where the firemen were practically helpless from the lack of water.

Water under pressure in the mains surrounding the scene of a potential fire is the silent watchman, ever on the job, ready to go into instant action with turning of a hydrant key or the melting of a sprinkler head fuse. It is the first line of defense in an incipient blaze —it extinguishes the last spark of a conflagration.

Nor should the part played by the telephone and the telegraph signal systems be overlooked—these services are indispensable. Quick communication results in prompt action on the part of the fire and the water departments. The Police Department likewise renders valuable service at times of fire by clearing the streets for the fire force and keeping crowds at a distance. All of these forces properly coordinated will, if the facilities are good, make it impossible for the enemy fire to gain headway. The most recent conflagration in Japan that caused more than one thousand persons to lose their lives and destroyed an entire city is another horrible example of the damage that can be wrought by the uncontrolled fire.

I wish here to present my views on some phases of the subject that has been assigned to me, the observance of which I believe will improve the effectiveness of fire fighting.

Groups formed for fire control study, such as may be found in local Fire Prevention Committees or other civic bodies, can accomplish much in organizing coöperation for utilizing all facilities for protecting property, preventing fires and extinguishing them; not the least important of which is the effective utilization of the water supply in the campaign for reduced fire losses.

In order that the water facilities for fire fighting may be satisfactory, there must be a relatively large volume of water available to the fire department near the fire or within a reasonable pumping distance. This implies large mains and a sufficient number of hydrants of ample capacity properly spaced. There is no economy in small hydrant branches with small hydrants in the present day of powerful pumping engines with which the modern fire department is equipped.

It is important, therefore, that the governing bodies of cities shall be educated to this necessity, otherwise cities will pay a heavy penalty through increased fire losses and fire insurance premiums. This education can best be accomplished by the coöperation of the fire department, the water department and the civic authorities, resulting in the appropriation of necessary funds to correct deficiency in water supply and other fire fighting facilities.

Fires cannot always be prevented, but when they occur they must be extinguished in the shortest possible time and with the least loss of value. Foresight must be applied in anticipation of this contingency; it is necessary that hydrants shall always be maintained in good working condition and such condition will not exist if they are used by untrained men for many purposes other than the extinguishment of

fires. Good maintenance of hydrants implies frequent inspection and testing so that when the emergency arrives they will be in good operating condition. The same is true of valves in the pipe system. It frequently happens that because of a broken main during a fire, it is necessary to make a quick shut-out. A faulty valve or hydrant is worse than none at all. Trained men with long experience and familiarity with the distribution system are just as necessary for effective and quick action as the system itself. Untrained men can cause expensive delays and no end of trouble.

Hydrants should always be accessible and usable. They should never be concealed from view. It is a good plan to keep hydrants well painted with light colors so that they may be seen at a distance. Yellow paint is admirable for this purpose.

Pumper nozzles on hydrants should be utilized where they exist. There is sometimes a reluctance on the part of firemen to attach pumpers at once rather than hose lines. This practice is not conducive to the most effective means of combating fire. All fire chiefs know the value of pumpers, but some of them do not take full advantage of them in the early stages of fires.

Fire authorities realize that a 6- or an 8-inch main will furnish but a certain number of hose streams and that when a greater demand is made all of the streams suffer. Advance studies of the distribution system around all important properties will probably show that within a short distance there are large mains which will furnish adequate volume when hooked up to pumpers. A wide distribution of pumpers is often an advantage in a large fire.

Familiarity with pipe sizes, hydrant locations, dead ends, closed valves, valves with kinked stems, hydrants temporarily out of repair, mains temporarily out of service, blockaded streets or bridges and full information in advance of an imaginary fire will mean that the battle is half won before it starts. This is only obtained by coöperation between the fire and water departments. It will be helpful to have posted in every engine house a good map of the distribution system so that firemen may study it for the most effective use of the water facilities available in any locality. Quick and accurate decisions may then be made when the occasion arises for utilizing them.

Fire flow tests are exceedingly valuable and their study will help materially in the efficient utilization both of the water supply and the fire apparatus. These flow tests are periodically made by the National Board of Fire Underwriters, but if additional flow tests are

made by the water plant superintendent coöperating with the fire chief they will give much valuable information.

An adequate automatic sprinkler system backed up by an excess or superior flow of water furnishes an excellent first line of defense in the event of fire; but unless it is maintained in good operating condition it is useless. There have been instances of closed valves or frozen feeder pipes, which have destroyed its usefulness. The success of the automatic sprinkler depends upon the adequacy of the water service behind it and the integrity of its maintenance. This branch of fire protection has a distinct and separate function to perform in reducing fire losses and reducing unemployment which probably would follow a disastrous fire in an industrial establishment. The automatic sprinkler is therefore a powerful ally in the fight.

The National Board of Fire Underwriters has adopted certain standards by which cities are graded according to their ability to cope with fires. Out of a possible 5,000 penalty points the water supply may be charged with as many as 1,700 points and the fire department with as many as 1,500. From these figures it will be noted that authorities place a high value on an adequate supply of water and on the efficient utilization of that supply. The efficiency of the public fire protection service will be enhanced if the fire chief and water plant superintendent will coöperate in a careful study of these reports, translating these studies into action before the city authorities whose duty it is to improve water and fire fighting facilities upon the recommendation of the fire chief and/or water plant superintendent.

It is also incumbent upon the water department to utilize all of the fire fighting facilities at its command; to be prepared at all times to deliver an ample volume of water to the fire force as and when demanded. Of what avail is a large storage reservoir if at a time of fire it is practically empty; in other words, if it is not maintained at a level that will provide the maximum fire flow that a conflagration may require? Of what avail is a fire pump or pumping engine held in reserve, if it is not maintained in operating condition and ready at any moment to meet a sudden fire emergency? The boiler plant must also be ready for instant response to the demand for more steam—day or night. The pumping stations must not fail.

Alertness on the part of the water utility is as necessary as alertness on the part of the fire department if fire fighting facilities are to be fully utilized.

I conclude from the foregoing remarks that:

1. Battles with fires are won by the fire fighting forces making the most effective use of the ammunition supplied by the water departments with equal credit to both.

2. Coördination of all fire fighting facilities are essential to success.

3. Public spirited citizens coöperating with city officials can promote this coördination.

4. Water mains must be sufficiently large to supply the volume of water required and hydrants must be properly sized, spaced and in good working order.

5. Familiarity with the distribution system and fire flow is necessary in planning for fire contingencies.

6. Preparedness and alertness on the part of those charged with the responsibility of protecting lives and property from fire loss is most important.

Without close observance of these and other principles, effective fire service will be practically impossible and heavy fire losses will result.

(*Presented before the Indiana Section meeting, April 13, 1934.*)

INCOME AND OPERATING COSTS FOR WATER SUPPLY FOR VARIOUS CITIES FOR 1932

By William C. Rudd, *Assistant Engineer—Power*

AND

Arthur C. Michael, *Field Engineer—Construction*

Department of Water Supply, Detroit, Mich.

For the purpose of comparing unit cost of water in various cities, the Department of Water Supply of Detroit sent out questionnaires to about 200 cities and received information from about 50 of them, so as to prepare cost data on revenue and operating costs. From this information the unit costs were prepared, as shown in table 1. Data were requested on gross annual revenue, operating expenditures, interest on bonded indebtedness, bond retirement expense, sinking fund payments, the amount of water supplied to distribution system and the amount of water sold. This information was then set up on an especially prepared sheet and the unit costs calculated. A second questionnaire form was sent to the various cities which showed the gross annual revenue, operating and maintenance cost less depreciation, total fixed charges, water pumped or supplied to the distribution system, and the amount of water sold. By dividing the latter two items into each of the other items, the costs per 1000 cubic feet of water sold or water delivered to the distribution system was obtained for each item of income and expense.

The second questionnaire showing all the unit costs was then sent to each respective city to check and return to the Detroit Department Water Supply.

Upon receipt of the second questionnaire checked by the respective city, the figures obtained were entered upon a chart as indicated in table 1.

The Detroit Department of Water Supply assumes no responsibility for the accuracy of this tabulation, but has every reason to believe that the data are reliable.

It is realized that the different cities have widely different problems

TABLE 1

Water revenue and expense data for various cities for 1932

CITY	POPULATION IN 1930, THOUSANDS	AMOUNT OF WATER PUMPED TO MAINS IN 1932, MILLIONS OF GALLONS	WATER DELIVERED TO DISTRIBUTION SYSTEM				REVENUE WATER OR WATER SOLD			
			Cost per 1000 cu. ft.				Cost per 1000 cu. ft.			
			Production	Fixed charges	Total expense	Revenue	Production	Fixed charges	Total expense	Revenue
Arkon, Ohio	253.65	7,034	0.315	1.121	1.436	1.207	0.408	1.452	1.860	1.564
Albany, N. Y.	127.36									
Ann Arbor, Mich.	26.87	1,363	0.316	0.451	0.767	0.982	0.388	0.553	0.941	1.204
Atlanta, Ga.	266.56	10,925.7	0.284	0.207	0.491	1.206	0.406	0.296	0.702	1.724
Baltimore, Md.	801.74	36,712.1	0.345	0.398	0.743	0.744	0.380	0.437	0.817	0.818
Battle Creek, Mich.	43.3	1,622.0	0.395	0.000	0.395	0.712	0.492	0.000	0.492	0.888
Bay City, Mich.	47.355	1,379.35	0.503	0.781	1.284	1.463	0.668	1.036	1.704	1.940
Buffalo, N. Y.	572.22	38,906.7	0.185	0.222	0.407	0.459	—	—	—	—
Camden, N. J.	117.17	5,581.2	0.369	0.143	0.512	0.763	0.535	0.207	0.742	1.106
Charleston, S. C.	62.265	1,625.2	0.581	0.461	1.042	1.449	0.766	0.607	1.373	1.908
Chicago, Ill.	3,375.23	368,494.7	0.154	0.038	0.192	0.255	—	—	—	—
Cincinnati, Ohio	449.33	20,052.2	0.436	0.258	0.694	0.850	0.614	0.354	0.968	1.169
Cleveland, Ohio	901.37	50,800.9	0.315	0.325	0.640	0.843	0.419	0.433	0.852	1.124
Columbus, Ohio	289.05	10,883.0	0.348	0.469	0.817	0.839	0.498	0.672	1.170	1.201
Covington, Ky.	62.25	1,807.8	0.576	0.532	1.108	1.268	0.692	0.640	1.332	1.524
Dearborn, Mich.	50.06	3,427.7	0.743	0.406	1.149	0.814	0.840	0.459	1.299	0.921
Detroit, Mich., 1928	1,720.0	78,060.2	0.178	0.247	0.425	0.537	0.228	0.316	0.544	0.687
Detroit, Mich., 1929	1,838.0	91,025.4	0.178	0.234	0.412	0.529	0.231	0.303	0.534	0.687
Detroit, Mich., 1930	1,869.0	94,184.4	0.178	0.234	0.412	0.526	0.232	0.304	0.536	0.685
Detroit, Mich., 1931	1,749.0	87,379.0	0.184	0.285	0.469	0.548	0.235	0.364	0.599	0.701
Detroit, Mich., 1932	*1,642.0*	*80,741.8*	*0.195*	*0.394*	*0.589*	*0.553*	*0.249*	*0.503*	*0.752*	*0.707*
Detroit, Mich., 1933		75,251.5	0.155	0.189*	0.344	0.559	0.204	0.249*	0.453	0.736
Erie, Pa.	115.87	6,946.0	0.391	0.101	0.492	0.641	—	—	—	—
Findlay, O.	19.33	514.23	0.681	0.502	1.183	1.321	0.851	0.628	1.479	1.652
Flint, Mich.	156.42	4,974.5	0.310	0.418	0.728	1.017	0.399	0.537	0.936	1.307
Fort Wayne, Ind.	115.12	2,860.8	0.662	0.542	1.204	1.422	0.923	0.754	1.677	1.980
Grosse Pte. Farms, Mich.	3.53	653.5	0.448	0.246	0.694	0.841	0.534	0.293	0.827	1.002
Hamilton, Ont., Can.	155.55	7,989.1	0.165	0.446	0.611	0.710	—	—	—	—
Hartford, Conn.	16.41	6,375.3	0.385	0.480	0.865	1.188	0.500	0.624	1.124	1.542
Highland Park, Mich.	52.82	2,698.3	0.427	0.252	0.679	0.822	0.472	0.279	0.751	0.909
Houston, Tex.	289.43	8,806.8	0.281	0.318	0.599	0.986	0.446	0.504	0.950	1.564
Jacksonville, Fla.	129.68	3,845.7	0.327	0.268	0.595	0.917	—	—	—	—
Kalamazoo, Mich.	54.39	1,787.4	0.398	0.013	0.411	0.982	0.540	0.017	0.557	1.330
Lansing, Mich.	78.42	2,338.1	0.458	0.538	0.996	1.077	0.574	0.673	1.247	1.349
London, Ont.	71.15	1,833.6	0.476	0.572	1.048	1.474	0.569	0.684	1.253	1.763
Los Angeles, Cal.	1,231.73	75,489.6	0.359	0.437	0.796	0.953	0.375	0.456	0.831	0.995
Louisville, Ky.	307.81	13,966.9	0.293	0.0306	0.3236	0.8399	0.419	0.0437	0.4627	1.199

TABLE 1—*Concluded*

CITY	POPULATION IN 1930, THOUSANDS	AMOUNT OF WATER PUMPED TO MAINS IN 1932, MILLIONS OF GALLONS	WATER DELIVERED TO DISTRIBUTION SYSTEM — Cost per 1000 cu. ft.				REVENUE WATER OR WATER SOLD — Cost per 1000 cu. ft.			
			Production	Fixed charges	Total expense	Revenue	Production	Fixed charges	Total expense	Revenue
			Does not include Sinking Fund for Miami Water Co.—This is a joint system.							
Miami, Fla.	110.51	3,797.4	0.618	0.494	1.112	1.414	0.753	0.602	1.355	1.724
Milwaukee, Wis.	572.32	29,020.7	0.228	0.0046	0.2326	0.649	0.292	0.0059	0.2979	0.829
Minneapolis, Minn.	462.61	18,910.8	0.308	0.127	0.435	0.540	0.421	0.174	0.595	0.740
Montreal, Que., Can.	818.58	56,071.7	0.140	Unknown		0.818	0.219	Unknown		1.278
Nashville, Tenn.	139.60	6,106.3	0.390	0.329	0.719	0.742	0.571	0.482	1.053	1.089
Newark, N. J.	442.77	18,477.6	0.495	0.614	1.109	0.843	0.547	0.679	1.226	0.932
New York City, N. Y.	6,959.19	328,500.0	0.220	0.409	0.629	0.576	0.271	0.504	0.775	0.710
Norfolk, Va.	127.81	4,406.0	0.342	1.040	1.382	1.482	—	—	—	—
Paducah, Ky.	33.54	887.9	0.390	0.889	1.279	1.686	0.461	1.050	1.511	1.991
Philadelphia, Pa.	1,961.46	111,321.0	0.141	0.127	0.268	0.434	—	—	—	—
Pontiac, Mich.	61.50	1,613.8	0.394	0.771	1.165	1.432	0.586	1.147	1.733	2.130
Raleigh, N. C.	37.51	1,010.1	0.594	0.973	1.567	1.531	0.686	1.123	1.809	1.767
Rochester, N. Y.	325.02	10,200.8	0.427	0.573	1.000	1.033	0.590	0.791	1.381	1.426
Royal Oak, Mich.	22.90	470.5	0.792	1.583	2.375	2.082	0.923	1.846	2.769	2.429
Saginaw, Mich.	80.72	3,359.7	0.366	0.749	1.115	1.099	0.955	1.957	2.912	2.869
San Antonio, Tex.	254.56	7,562.0	0.289	0.432	0.721	0.998	0.394	0.588	0.982	1.359
Syracuse, N. Y.	207.01	10,848.0	0.199	0.343	0.542	0.559	0.418	0.722	1.140	1.173
St. Paul, Minn.	270.88	8,203.5	0.433	0.425	0.858	0.939	0.519	0.509	1.028	1.124
Tacoma, Wash.	106.84	8,980.3	0.149	0.394	0.543	0.591	—	—	—	—
Tampa, Fla.	100.91	3,125.9	0.640	0.497	1.137	1.254	0.820	0.638	1.458	1.607
Toledo, O.	290.79	10,917.7	0.751	0.141	0.892	0.809	—	—	—	—
Washington, D. C.	485.72	31,708.9	0.253	Unknown		0.479	0.418	Unknown		0.792
Windsor, Ont., Can.	63.108	2,876.0	0.314	0.409	0.723	0.782	0.403	0.525	0.928	1.004

* Refunding plan; fixed charges reduced.

in water supply and that comparative costs do not necessarily give a correct valuation of the whole situation. However, from a purely financial viewpoint, these figures show the variations of water costs throughout the country and tend to indicate the importance of fixed charges to operating income and the costs of waste and use of free water by municipalities.

ABSTRACTS OF WATER WORKS LITERATURE

FRANK HANNAN

Key: American Journal of Public Health, 12: 1, 16, January, 1922. The figure 12 refers to the volume, 1 to the number of the issue, and 16 to the page of the Journal.

Treatment of the Water Supply of Wellsburg, W. Va. M. J. DAVIS and W. J. HERVEY. The American City, **48**: 5, 43–45, May, 1933. Water, derived from two Layne wells 24 inches in diameter and about 70 feet deep, contains iron and some dissolved gases and is too hard for domestic consumption. Aërator, consisting of large superposed trays of lump coke, helps to remove sulphur gases and carbon dioxide. Iron removal is accomplished in three Permutit steel pressure filters, from which water passes through Scaife zeolite treatment devices, where hardness is reduced from 13 to about 6 grains per gallon. After softening it is pumped to storage reservoir, from which distribution system is fed by gravity. Chlorine is added as sterilizing agent.—*Arthur P. Miller.*

The Water Supply for Boulder City, Nevada. W. R. NELSON. The American City, **48**: 5, 51–53, May, 1933. Colorado River, with average hardness of 367 and average silt content of 6,000 p.p.m., is source of supply. Intake plant is located 3,000 feet downstream from dam site and consists of three 550-gallon-per-minute 115-foot head centrifugal pumps mounted on movable carriage, adjustable to river level, and delivering into pre-sedimentation basin equipped with traction clarifier and sludge removal pump, where 97 percent of silt is removed during detention period of 2½ hours. Water thus clarified flows to sump tank from which it is lifted by three 500-gallon-per-minute 1,150-foot head centrifugal pumps to pumping plant #2, where similar equipment forces it to aërator at top of 100,000-gallon tank in Boulder City. All pumps are automatically controlled and pipe lines are equipped when necessary with automatic air valves and surge suppressors. Water after aëration is clarified, softened, and filtered; after which, it passes to distribution system.—*Arthur P. Miller.*

The Maintenance of Water Meters. CHARLES W. DAVIS, JR. The American City, **48**: 5, 54, May, 1933. At Petersburg, Va., standardization of meters reduced maintenance costs by rendering available for replacement purposes, parts salvaged in good condition from old meters. Interchangeability of meter parts is principle involved.—*Arthur P. Miller.*

Zinc in Relation to General and Industrial Hygiene. CECIL K. DRINKER and LAWRENCE T. FAIRHALL. Public Health Reports, **48**: 32, 955, August 11,

1933. Pure zinc, in contrast to metals such as arsenic, lead, antimony, and cadmium, has no poisonous qualities even if taken in large amounts. Both taste and appearance act to prevent zinc in its most common form from being a persistent contaminant of water supplies even in amounts which are harmless. All of the readily soluble zinc salts possess an unpleasant, astringent taste which most people can detect in water before there is a possibility of taking in enough to produce gastric irritation. When these salts contaminate food, their taste is easily disguised, and amounts irritating enough to cause vomiting can readily be ingested. Zinc in food and in relation to industrial hygiene is discussed. Public Health Service Reprint 1029, published in 1925 placed a limit of 5 p.p.m. of zinc in drinking water. The authors summarize their investigation as follows: Since the zinc ion is not of itself poisonous, and many times five parts per million may be taken without harmful effects, it is suggested that this limit, which gives a relatively innocuous metal an undeserved reputation for toxicity, be increased or done away with altogether; foods or beverages, with exception of simple or chlorinated drinking water, should not be stored in zinc-lined or galvanized containers; a single industrial condition arises from zinc and this condition is not produced by zinc alone. This is the "zinc chill," better known as metal fume fever. The different groups of symptoms described as chronic industrial zinc poisoning, together with other complex ills which have been ascribed to zinc, may be disregarded, as they are due to contamination by other substances.—*A. W. Blohm.*

Water Supply of Delmhorst, Germany. GEORGE FRANKE. (Translated by G. K. EGER and T. R. MCCREA.) The ground water in the neighborhood of Delmhorst has an iron content of 9 p.p.m., manganese 0.5 p.p.m., free CO_2 and a high content of dissolved organic substances with humic acid characteristics, all of which are undesirable in drinking water. Up to 1926 when it was decided to enlarge the plant, the water had been treated by purling over coke, settling, primary and secondary filtering, using potassium permanganate as the precipitating agent. The contractors for the new works agreed to build a plant to produce a satisfactory water, changing the design by omitting the coke purling process and substituting a larger and higher purling, thus eliminating the need for annually renewing the coke beds. They further planned to lower the expenditure for chemicals by substituting iron sulphate for potassium permanganate. After completion the plant did not meet the requirements and it was necessary to install a coke purler, to increase the size of the settling basins and to add the filter of the old plant to the new units. Potassium permanganate was found to be more satisfactory than the iron sulphate. After all changes were made it was possible to reduce the iron to 0.03 p.p.m., the manganese to zero and the aggressive CO_2 to 2.5.—*A. W. Blohm.*

Deep Tube Well Waters of Bengal. RAV BAHADUR V. GORINDA RAJU. Indian Journal of Medical Research, 19: 2, 477, October, 1931. Within the last 10 years deep tube wells have become a favorite source of drinking water in various parts of Bengal. Samples from over 150 wells have been examined on one or more occasions. Systematic monthly examinations were made on 23 wells for a period of 2 years, and daily examinations were made on 6 wells for a

period of 3 months beginning before the onset of the rains. The water, as a whole, is practically sterile but lactose fermenters are obtained from the wells not infrequently, which is probably due to the corrosive action of the water causing leaks in the well casing and thus allowing these organisms to enter the water. Eighty percent of these lactose fermenters were of the aerogenes type and 20 percent were of the coli type. The chemical findings show the water to be of low salinity not exceeding 20 p.p.m. (as chlorine) except in wells located near tidal rivers or flats; the hardness is high, the permanent hardness is around 40 or 50 p.p.m. and the temporary hardness is seldom under 200 p.p.m.; free NH_3 may be present in excess; organic matter is practically negligible as judged from the permanganate consumed test; iron is frequently found in large amounts but it may also be totally or practically absent.—*A. W. Blohm* (*Courtesy U. S. P. H. Eng. Abstracts*).

Flow of Ground Water as Applied to Drainage Wells. M. R. Lewis. Proc. American Soc. C. E., **57**: 3, 411, March, 1931. Three types of wells are discussed: (*a*) Artesian wells (not necessarily flowing) with a perforated casing extending through the water bearing stratum; (*b*) wells in which the water table is in the water bearing stratum and which penetrate its full depth; (*c*) open bottom wells, that is, wells which just reach the water bearing stratum. Cases in which the zone of influence is either definite or indefinite are considered for each type, and formulas for the draw down curves for each of these types of wells are derived. The author concludes that if the area to be drained is more than a few hundred feet in diameter, successful drainage will depend on a general lowering of the ground water table; to secure this lowering, wells should be designed to have the greatest possible capacity with an economical lift. Such capacity may be secured most readily, where conditions are favorable, by deep wells.—*A. W. Blohm* (*Courtesy U. S. P. H. Eng. Abstracts*).

Twenty-fifth Annual Report of the Board of Water Supply of the City of New York. January 1, 1931. This report describes the various activities of the Board for the calendar year of 1930, including detailed financial statements of expenditures on various projects and a report of the chief engineer. Preliminary investigations looking to the provision of additional sources of water from Rondout Creek and tributaries of the Delaware River were conducted throughout the year. Construction work on City Tunnel No. 2 has been carried forward and at the end of the year was 44 percent completed. This tunnel 17 feet in diameter and 20 miles long, extends from the Hill reservoir in Yonkers through the Borough of the Bronx, Queens and Brooklyn to South Brooklyn. An appendix contains a historical record of the various transfers of completed portions of the Catskill water supply system from the Board of Water Supply to the Department of Water Supply Gas and Electricity for routine operation.—*A. W. Blohm* (*Courtesy U. S. P. H. Eng. Abstracts*).

The Sheboygan Filtration Plant. Arthur H. Miller. The Municipality, **26**: 11, 215, November, 1931. A description of the new $430,000 filtration plant of standard type. Much effort has been made to enhance the beauty of the

interior and exterior. Plant consists of aerators, mixing tanks, sedimentation basins, filters and clear well. Raw water obtained from impounded reservoir from which water is pumped to head of filtration plant.—*A. W. Blohm* (*Courtesy U. S. P. H. Eng. Abstracts*).

Water Works Improvements at Grants Pass. JOHN W. CUNNINGHAM. Western Construction News, **6**: 20, 561, October 25, 1931. This article describes the new water filtration plant at Grants Pass, Oregon, and changes in the distribution system and reservoirs. The source of supply is the Rogue River. The treatment consists of pretreatment with ammonia and chlorine, addition of alum and hydrated lime and filtration by gravity rapid sand filters. —*A. W. Blohm* (*Courtesy U. S. P. H. Eng. Abstracts*).

Control of Typhoid in Richmond County, North Carolina. A. B. MCCREARY. Journal of the American Medical Association, **97**: 14, 998, October 3, 1931. The article describes typhoid control in Richmond county from the standpoint of health education and sanitation. The decrease in typhoid among negroes and the more ignorant white population is attributed to the following: (1) information by word of mouth is given to the uneducated public concerning typhoid and the value of better hygienic conditions; (2) improved sanitary conditions, grade A milk, inspected foods and adequate sewage disposal cannot, with this type of person, be put over by pamphlets and newspapers: they must hear the word; (3) the coöperation of the public and of the medical profession in an oral program is essential; (4) the assistance of the newspapers with this class is useful only so far as educated persons are stimulated to impart information orally.—*A. W. Blohm* (*Courtesy U. S. P. H. Eng. Abstracts*).

Typhoid Carriers Surveyed. Weekly Bulletin, California Department of Public Health, **10**: 51, 203, January 23, 1932. Dr. A. H. Hieronymous, City Health Officer of Oakland, and Dr. R. W. Sanders, City Health Officer of Alameda, have just completed surveys of known typhoid fever carriers residing in their respective cities. Specimens were obtained from all such carriers and examinations were made in the laboratories in order to determine if such individuals are still carriers. Information relative to the compliance of such carriers with regulations for their control was also obtained. These health officers plan to make similar surveys at least twice each year. This procedure receives the commendation of the State Department of Public Health, since it provides an efficient check upon typhoid carriers.—*A. W. Blohm* (*Courtesy U. S. P. H. Eng. Abstracts*).

Relation of Typhoid Carriers to Food Supply. G. W. ANDERSON. The Commonhealth, Massachusetts Department of Public Health, **18**: 2, 93, April-May-June, 1931. "The recognized typhoid carrier is unquestionably the most important factor today in the spread of typhoid fever in Massachusetts." Water-borne and milk-borne epidemics have mostly had their day. The typhoid carrier escapes notice because he has no unusual characteristic appearance. Three things are necessary, acting in proper sequence to bring about infections from a carrier: (1) organisms must be shed on the day in question;

(2) the hands must be infected from the discharges; (3) these soiled hands must be used in the preparation of food that will not be further cooked. No system for keeping carriers away from food handling has so far been devised which is more satisfactory than individual responsibility on the part of the employer. It is encouraging to note that employers are realizing this.—*A. W. Blohm* (*Courtesy U. S. P. H. Eng. Abstracts*).

Typhoid Carriers of 1931. Weekly Bulletin, California Department of Public Health, 10: 45, 179, December 12, 1931. A total of 21 typhoid carriers has been found in California during the present year. Seventeen of these are casual carriers and four are convalescents, who continue to harbor the typhoid organisms following recovery from attacks of the disease. Eleven of the 21 carriers were discovered by health officers of the various cities of California. Two were discovered by county health officers and the remaining eight carriers were discovered by the State Department of Public Health. A total of 40 cases of typhoid fever which occurred this year has been traced to these carriers. The largest number of cases for which a single carrier was responsible is eighteen. These occurred on a raw milk dairy route.—*A. W. Blohm* (*Courtesy U. S. P. H. Eng. Abstracts*).

A Study of Epidemic Catarrhal Jaundice. Roy Fraser. Can. J. Pub. Health, 22: 396–411, 1931. Epidemic of 173 cases of "catarrhal" jaundice, preceded by epidemic of 600 cases of gastro-enteritis, at 3 educational institutions in Sackville, N. B., was studied from clinical, epidemiological and bacteriological standpoints. Epidemiological evidence tended to incriminate one of three water supplies used. Organism responsible was not isolated from supply in question, and etiological evidence is purely serological. Agglutination tests in relatively high dilutions indicated that causative organism was *Salmonella schottmülleri*. Agglutinins for *Salmonella paratyphi* were observed, and were shown by absorption to be group agglutinins. Two of water supplies contained leptospiras; but clinical, bacteriological, and serological evidence rules out possibility of any type of leptospira being etiological agent. Suspected supply contained *Cl. welchii* in large numbers, in addition to colon bacilli. Literature is extensively reviewed, and bibliography of 49 references is appended.—*R. E. Thompson* (*Courtesy Chem. Abst.*).

Concord, N. H., Drives 150 Wells to Avert Water Shortage. Eng. News-Rec., 107: 501–2, September 24, 1931. Description of new additional source of supply of Concord, recently completed at cost of $150,000. Penacook Lake has been source of supply for many years. New development consists of 150 wells, yielding 1.5 million gallons per day, driven 45 feet to rock in Soucook River valley, 3 miles from city. Wells are staggered at 40-foot intervals along several header pipes converging into 12-inch main line feeding 2 centrifugal pumps. Incorporated in supply line to pumps is combined sand chamber and vacuum tank, in which vacuum is automatically maintained by vacuum pumps, thus providing automatic priming for main pumps. Lake Penacook water is chlorinated, but new supply is pumped directly into mains without treatment. —*R. E. Thompson.*

The Technique of the Determination of Stream Pollution. A. V. DeLaporte. Cont. Rec. and Eng. Rev., **45**: 990–1, 1931. Brief discussion of procedure for stream pollution investigations, including selection of sampling points, collection of samples of water and of bottom deposits, and necessary tests. Tabulated data on the composition of various industrial wastes are included.—*R. E. Thompson* (*Courtesy Chem. Absts.*).

Experiments in Gunite Control at Syracuse Reservoir. E. P. Stewart. Eng. News-Rec., **107**: 807–10, November 19, 1931. Westcott Reservoir in Syracuse is a lined-earth distributing reservoir of 107 million gallons capacity, 1090 feet long, 250 feet wide, and 40 feet deep, with inside bank slopes of 1 on 2, 87 feet wide. Plans called for 3½ inches of gunite, directly, on clay bottom, and over 6-inch crushed stone underlining, on slopes. A 6-inch tile drain with open joints was installed at toe of slope, connected to cast iron drain extending through embankment. Expansion joints, extending from curb to toe wall, were placed at intervals of about 120 feet, bottom panels being of about same dimensions. Joints were fitted with copper water stops and filled with plastic material. Gunite was placed in 2 layers (1 and 2½ inches) with steel wire reinforcing mesh between. Laboratory and field tests showed that strength of gunite bears definite relation to nozzle velocity at which it is shot, velocity of about 375 feet per second producing maximum strength. It was found that water-cement ratio of 0.55 was lowest practicable at which to shoot material. Range of 0.55 to 0.65 is recommended. Fineness coefficient of sand used also bears definite relation to strength. Effects of these 3 factors on strength, absorption, and rebound, as indicated by results of over 500 laboratory tests, is shown graphically.—*R. E. Thompson.*

Low Stream Flows Again Cause Concern in Southeastern States. Eng. News-Rec., **107**: 817, November 19, 1931. Brief data. Record low flows over wide area have seriously affected power development and are rapidly becoming hazardous to water supplies.—*R. E. Thompson.*

The Problem of Stream Pollution in Canada. George H. Ferguson. Cont. Rec. and Eng. Rev., **45**: 856–7, 1931. Brief discussion of stream pollution in Canada, with particular reference to boundary waters.—*R. E. Thompson* (*Courtesy Chem. Absts.*).

Masonry Wall Masks Steel Standpipe. Eng. News-Rec., **107**: 1011, December 24, 1931. Brief illustrated description of recently completed 1,700,000-gallon masonry-inclosed standpipe in residential section of Scarsdale, N. Y., so pleasing in architectural appearance as to be an asset to neighborhood. Water supply, purchased from the Pocantico Water Co., enters village from east, where 750,000-gallon steel standpipe floats on line, and is carried to west side, where new standpipe is located, by 16-inch main. Steel tank, 54 feet in diameter and 101 feet high, is of conventional riveted construction with exterior coating of aluminum graphite. Surrounding tank, at clear distance of 4 feet, wall 4 feet thick at base has been constructed of native masonry trimmed with Maine granite. In annular space, curved stairway extends from ground

to roof. Roof, of steel plate supported by flat trusses, spans both standpipe and wall. Total cost of structure was $135,000, of which $44,000 was for inner steel tank erection. New standpipe will be provided in near future with auxiliary supply pumped from aqueduct of New York City water system.—*R. E. Thompson.*

Detroit Uses Temporary Pumping Plant in Summer Months. WILLIAM C. RUDD. Eng. News-Rec., 107: 530, October 1, 1931. Brief description of 51-m.g.d. pumping plant operated in conjunction with new filtered water reservoir in Detroit to assure adequate service in western part of city pending completion of new Springwells plant. Reservoir is filled from distribution system during hours of low demand and pumps are operated from late afternoon until late evening. Equipment will be transferred to permanent plant when completed.—*R. E. Thompson.*

Water Supply Tests Employed for Isolation of the Colon Group of Bacteria. NORMAN J. HOWARD. Cont. Rec. and Eng. Rev., 45: 748–50, 1931. Review and discussion of history of *B. coli* test and of modifications suggested for overcoming limitations of lactose broth as preliminary enrichment medium. Need of further research work is emphasized.—*R. E. Thompson* (*Courtesy Chem. Absts.*).

Tunnel Driving at Cobble Mountain. HARRY H. HATCH. Eng. News-Rec., 107: 507–11, September 24, 1931. Detailed description of construction of 1550-foot diversion tunnel and 7080-foot pressure tunnel, major features of Cobble Mountain project of Springfield, Mass. Former is of $11\frac{1}{2} \times 11\frac{1}{2}$-foot horseshoe section and latter, mainly of $10 \times 9\frac{1}{2}$ foot horseshoe section. Drilling, shooting, and mucking methods employed are discussed and compared. Project is most opportune proposition both for city and for power company which has contracted to purchase power developed. City would have been unable at this time to develop watershed to full capacity without financial returns from power company; and latter has acquired most important water-power site within its territory to meet needed requirements without other financial obligation than yearly payment of rental. Analysis of actual cost of excavation is included.—*R. E. Thompson.*

Tunnel Concreting and Surveying at Cobble Mountain. HARRY H. HATCH. Eng. News-Rec., 107: 988–90, December 24, 1931. Concrete-lining methods employed on Cobble Mountain tunnels are described. In diversion tunnel, invert was poured first with short side walls, then remaining sidewalls and arch were poured in one operation using regular steel forms. In pressure tunnel, invert, sidewalls, and arch were poured separately, using steel-lined wooden forms for arch and sidewalls. A 1:1 mortar of sand and cement was used for patching. In some cases, where spots were too wet to support patches, mixture of water glass and cement, which set completely in about 30 seconds, was employed. Methods used for controlling lines and grades are outlined.—*R. E. Thompson.*

Tunnel Grouting at Cobble Mountain Dam. HARRY H. HATCH. Eng. News-Rec., **107**: 1037–9, December 31, 1931. Description of grouting procedure employed in construction of Cobble Mountain tunnels. Details of amount of grout used, costs, etc., are included.—*R. E. Thompson.*

Steel Lining of Pressure Tunnels at Hoover Dam Recommended. Eng. News-Rec., **107**: 838, November 26, 1931. Colorado River Board recommends that steel plate lining be employed for main tunnels conveying water from reservoir to penstocks leading to power house and outlet works, concrete being considered inadequate for pressure involved, which will be 560 feet (240 pounds per square inch) when reservoir is full. Each of proposed spillways will have maximum discharge capacity of 200,000 second-feet, involving velocity in spillway tunnels approaching 180 feet per second, approximately double that of previous engineering experience. Every effort should be made to secure essentially monolithic concrete lining for these tunnels.—*R. E. Thompson.*

Building Boulder City. Eng. News-Rec., **107**: 846–9, November 26, 1931. Water supply system of Boulder City, town created for accommodation of construction forces employed on Boulder Canyon project, consists of 200,000-gallon presedimentation tank, equipped for mechanical sludge removal, approximately 100 feet above Colorado River, 6¾ miles of 12-inch steel pipe, pumping stations, and 2-million gallon storage tank which will deliver water by gravity to city mains. Clarified water is lifted against 1100-foot head through 4 miles of pipe line to second pumping plant which lifts water further 900 feet through remaining 2¾ miles of line. Filter plant is under construction: in meantime water is being chlorinated only—*R. E. Thompson.*

Ontario Government's Regulations for Tunnel and Caisson Work. Cont. Rec. and Eng. Rev., **45**: 1215–7, October 7, 1249–51, October 14, 1931. Regulations governing tunnel and open caisson operations, recently announced through Ontario Gazette, are given.—*R. E. Thompson.*

First Six Months' Progress at Hoover Dam. Eng. News-Rec., **107**: 923–6, December 10, 1931. Outline of progress at Hoover Dam site during first 6 months of preliminary construction activity, including establishment of camps at Boulder City and at river, driving of more than 14,000 feet of pioneer tunnel top headings for four 50-foot diversion tunnels (56-foot inside rock: with 3-foot concrete lining) and considerable progress on enlargement of 3 of these tunnels from outlet portals, railroad and highway construction, etc.—*R. E. Thompson.*

Section B of Boston Traffic Tunnel. Eng. News-Rec., **107**: 388, September 3, 1931. Unit prices given from 3 lowest bids on section **B** of Boston traffic tunnel, which consists of steel and concrete tube 435 feet long, to be constructed by cut and cover method.—*R. E. Thompson.*

Ford Water Tunnel, Detroit. John F. O'Rourke. Eng. News-Rec., **107**: 584, October 8, 1931. Brief discussion of design of concrete block-lined tunnel of Ford Motor Co.—*R. E. Thompson.*

Tunnel for Saddle-Horse Use on New Glacier Park Trail. GEORGE W. REED. Eng. News-Rec., **107**: 730, November 5, 1931. Brief description of tunnel 183 feet long, 6 feet wide, and 9 feet high through solid rock ridge known as Ptarmigan Wall.—*R. E. Thompson.*

Stream Control Works on Swift River, Massachusetts. Eng. News-Rec., **107**: 388, September 3, 1931. Contract was let July 21 for stream control work at main dam of Swift River reservoir for $560,923. Work consists of excavating and lining (concrete) 1100 feet of tunnel and one shaft, and constructing appurtenant works. Unit costs given from 3 lowest bids.—*R. E. Thompson.*

Corrosion of Hot-Water Pipes Halted by Venting Feedwater Heater. A. W. BLOHM. Eng. News-Rec., **108**: 53, 1932. Treatment of rapid sand filtered water with soda ash to maintain pH value of 7.6 failed to prevent corrosion in hot water system of Maryland institution. Installation of vent condenser on boiler feed water heater, however, has proved effective, as indicated from Powell corrosion test plugs. Lime has been substituted for soda ash for adjustment of pH value.—*R. E. Thompson (Courtesy Chem. Abst.).*

New Hydraulic Laboratory at University of Tennessee. Eng. News-Rec., **107**: 724–5, November 5, 1931. Brief description.—*R. E. Thompson.*

Work Starts on a National Hydraulic Laboratory in Washington. BLAKE R. VAN LEER. Eng. News-Rec., **107**: 996–8, December 24, 1931. National hydraulic laboratory under construction, adjoining buildings of Bureau of Standards, will be operated under direction of GEORGE K. BURGESS, Director of Bureau. It is expected that structure will be ready for occupancy by April 1, 1932. Although being built primarily for study of hydraulic problems of federal government and its various engineering agencies, law provides that it may also be made accessible to state authorities and municipalities upon request. It will also be available to private engineers at actual cost of performance. Highly specialized and complete reference library is to be assembled in new building and laboratory will act as coördinating agency for all laboratories conducting hydraulic research in United States. Tabulation of maximum capacities of leading hydraulic laboratories of world is included for comparison.—*R. E. Thompson.*

E. B. Eddy Co.'s New Filtration Plant in Hull, Quebec. A. M. FOWLER. Cont. Rec. and Eng. Rev., **46**: 8–9, 1932. Brief description of new 20-m.g.d. rapid sand filter plant on Ottawa River, built at cost of $400,000. Alum and chlorine are applied in inlet well, which also serves as preliminary mixing chamber, incoming water from low-lift pumps providing necessary agitation. From well, water flows through mixing chambers and settling basins to filters. Lime for adjustment of alkalinity and secondary dosage of chlorine are added in clear well. Portion of the water can be used for certain processes without passing through filter plant, being subjected only to screening and chorination. Filtering medium consists of 18 inches of graded gravel and 32 inches of sand with effective size of not less than 0.4 mm.—*R. E. Thompson (Courtesy Chem. Abst.).*

Device Secures Accurate Samples from Subaqueous Silt Beds. R. W. ELLMS. Eng. News-Rec., **107**: 1011–2, December 24, 1931. Since completion of Holtwood dam of Pennsylvania Water and Power Company on Susquehanna River, enormous quantity of coal-laden silt has been deposited in lake above dam, beds extending for a mile along stream, in some places to depth of 60 feet. With view to investigating possibility of recovering the coal, core sampler was devised and patented by author by means of which true samples of material containing as much as 75 percent water can be collected at definite locations without sinking casings. It has successfully penetrated 30 feet of silt under 13 feet of water. Device is described briefly and illustrated.—*R. E. Thompson.*

History and Development of the Submarine Rock Drill. Eng. News-Rec., **107**: 763–5, November 12, 1931. Description and discussion of earlier and present day types of drills.—*R. E. Thompson.*

A Review of Waterworks and Sewerage Activities in Ontario. A. E. BERRY. Cont. Rec. and Eng. Rev., **45**: 1565, 158, 160, 162, 1931. Of 394 municipalities in Ontario, only 115 are not served by public water supply systems. Only 13 of those without public systems have populations in excess of 1000. Approximately 60 percent of supplies are of surface origin, 20 percent are derived from deep wells, and 15 percent from springs. Over 80 percent of all water supplied is chlorinated. Works in progress and contemplated are outlined.—*R. E. Thompson* (*Courtesy Chem. Abst.*).

Sanitation in Ontario Summer Resorts. A. E. BERRY. Can. J. Pub. Health, **22**: 293–5, June, 1931. Activities of Ontario Department of Health in regard to summer resorts are described briefly.—*R. E. Thompson.*

Sanitary Supervision of Roadside Accommodation in Ontario. E. W. JOHNSTON. Can. J. Pub. Health, **22**: 299–302, June, 1931. Outline of supervision of tourist camps in Ontario. Legislation does not provide for licensing, but only for granting of approval certificates and banners by Provincial Department of Health.—*R. E. Thompson.*

Sanitary Control of Summer Resorts in Quebec. THEO. J. LAFRENIÈRE. Can. J. Pub. Health, **22**: 285–7, June, 1931. Outline of organization of Provincial Bureau of Health and of activities in connection with summer resorts. —*R. E. Thompson.*

Rural Sanitation in Saskatchewan. R. H. MURRAY. Can. J. Pub. Health, **22**: 282–5, June, 1931. Outline of activities of Department of Health in field of rural sanitation, including water supply.—*R. E. Thompson.*

Sanitation in the Canadian National Parks. G. H. FERGUSON. Can. J. Pub. Health, **22**: 271–4, June, 1931. Brief outline of water supply and sewerage facilities.—*R. E. Thompson.*

Shaker for Sieving Sand or Cement. MELVIN L. HUGHES. Eng. News-Rec., **107**: 1010, 1931. Brief, illustrated description of inexpensive, home-made device.—*R. E. Thompson* (*Courtesy Chem. Abst.*).

Depreciation Plan is Set Up for Rail and Phone Companies. Eng. News-Rec., **107**: 466, September 17, 1931. All railroads and telephone companies have been ordered to establish, effective January 1, 1933, complete system of depreciation accounting at percentage rates to be fixed by Interstate Commerce Commission on basis of the companies' experience. Railroads have preferred and have used for property other than equipment, plan known as retirement plan, by which cost of wornout property is charged to expenses at time of retirement. Under Commission's plan, roads will be required to anticipate cost of retirement by charging to their expense account, monthly and annually, percentages for different classes of property based upon estimated service life. Commission maintains that depreciation must be based on original cost of property, whereas railroads contend that it should be based on cost of replacement. Commission has ordered roads to use as original cost estimate their valuation figures for cost of reproduction at 1914 prices, except where better estimates of actual original cost can be produced. Commission's order is result of 10 years' investigation following amendment of law adopted by Congress in 1920 instructing Commission to prescribe classes of property for which depreciation may properly be charged to operating expenses and to fix depreciation rates.—*R. E. Thompson.*

Recent Application of Draft Distributors to Power Plant Intakes. H. G. ACRES. Eng. News-Rec., **107**: 403–10, September 10, 1931. Detailed discussion of development of JOHNSON-WAHLMAN draft-distributor intake and of its application at several hydroelectric power plants.—*R. E. Thompson.*

Developments in Water Supply and Treatment. NORMAN J. HOWARD. Cont. Rec. and Eng. Rev., **45**: 1559–64, 156, 158, 1931. Comprehensive review of progress in 1931. Outstanding development during year was greatly extended use of activated carbon for removal of taste and odors. Some 170 plants in America now employ this material in treatment of water, or sewage. —*R. E. Thompson* (*Courtesy Chem. Abst.*).

Cast Iron Pipe River Crossing Installed Without Special Equipment. Eng. News-Rec., **107**: 702, October 29, 1931. Brief outline of laying of 10-inch cast iron pipe line by Endicott Water Company, N. Y., across stream 610 feet wide and 30 feet deep. Joints, which are of leadite, were poured in trench on shore, 3 lengths at time, and pipe was pulled into position with block and tackle. Crossing was installed by 5 men in 3 working days. After completion, tests were made with air and water at 140 pounds per square inch (service pressure 110 pounds). Leakage was only 14 gallons in 48-hour test period.—*R. E. Thompson.*

Steel Pipe Rolled after Welding. Eng. News-Rec., **107**: 703, October 29, 1931. In fabrication of 54-inch arc-welded steel storm sewer outlet at Grand

Rapids, Michigan, longitudinal seam was welded while curved steel plate was still in rolls and rolling then continued to straighten seam and insure true cylindrical section. Each pipe section was rolled from ¾-inch plate, 17 feet long and 8½ feet wide. Two sections, 8½ feet long, were butt-welded together to form field section and circumferential field joints were welded from inside of pipe.—*R. E. Thompson.*

72-Inch Water Conduit in Brooklyn. Eng. News-Rec., **107**: 712, October 29, 1931. Unit prices given from 3 lowest bids on construction of four 72-inch steel water conduits, totaling 2600 feet, in Brooklyn. Where not encased in concrete, exterior and interior are covered with bitumastic enamel. Contract was let for $230,865.—*R. E. Thompson.*

Co-operation in Water Purification. J. R. MENZIES. Cont. Rec. and Eng. Rev., **45**: 1102–3, 1931. Brief outline of activities of Department of National Health (Canada) in enforcement of regulations concerning water for drinking and culinary purposes on vessels navigating on Great Lakes and inland waters and on common carriers engaged in international and interprovincial traffic.—*R. E. Thompson* (*Courtesy Chem. Abst.*).

Water Supplies on Common Carriers. F. M. BRICKENDEN. Cont. Rec. and Eng. Rev., **45**: 1103, 1113, 1931. Additional data on enforcement of Canadian regulations governing water supplies on common carriers (cf. previous abstract). Cases of typhoid reported from vessels dropped from 50 in 1923, year in which work was commenced, to 2 in 1929.—*R. E. Thompson* (*Courtesy Chem. Abst.*).

Sixty-Inch Cast Iron Conduit Brings Water to Atlantic City. C. G. WIGLEY. Eng. News-Rec., **107**: 774–5, November 12, 1931. Water supply of Atlantic City is derived from sources, chiefly artesian wells, located on mainland, 5 miles from city. Construction of new 60-inch cast iron main, replacing wood-stave line which had been in service 25 years, for conveying supplementary surface supply for use in case of unusual drafts, is described. Water is also pumped into conduit from 10 artesian wells located along route. Leadite was employed as jointing material. Cost of pipe and fittings was $195,443.80 and of laying, jointing, etc., $76,520.75, or total cost of $28.33 per foot.—*R. E. Thompson.*

51-Inch Concrete Force Main, Little Falls, N. J. Eng. News-Rec., **107**: 594, October 8, 1931. Unit prices given on 51-inch cylinder-reinforced, concrete line (sewer force main) 20,575 feet long, contract for which was recently let for $369,466.—*R. E. Thompson.*

The Water-Sewage-Water Cycle. Discussion. Eng. News-Rec., **107**: 683–5, 1931. Cf. R. F. GOUDEY, C. A., **25**: 1928, 2790; K. IMHOFF, C. A., **25**: 4335. **Re-Use of Water in Desert Country.** JANE H. RIDER. 683–4. Preliminary investigations at Tucson, Ariz., where sewage, after mechanical clarification, is employed for irrigation, indicated that this practice leads to heavy pollu-

tion of ground water. Cost of sewage treatment is $3.42 per million gallons, while cost of ground water pumped to surface is approximately $20 per million gallons. In addition, sewage-irrigated land produces better crops. At Grand Canyon, Ariz., sewage purified by activated sludge treatment, rapid sand filtration, and chlorination, at cost of 57 cents per 1000 gallons is used for irrigation and industrial purposes. Water transported 100 miles in tank cars for domestic purposes costs $3.09 per 1000 gallons. **Economies of Commercial Use.** BURTON LOWTHER. 684. Irrigation, commercial, and semi-sanitary uses will in time accustom public to consider economic value of reclaimed water. **Absolute Necessity the Only Justification.** N. T. VEATCH, Jr. 684–5. While reclaimed sewage is especially adapted for irrigation, its use for direct replenishment of water supply will be resorted to only in case of necessity. Grand Canyon plant illustrates how thoroughly sewage can be treated, effluent meeting Treasury Department standard for drinking water. **Only for Isolated Cases.** H. W. STREETER. 685. It is improbable that water-sewage-water cycle will be intensified in this country to a degree comparable with that in Ruhr District, except possibly in limited areas. Practicability of such reclamation may be considered as limited to uses such as irrigation, industrial supply, etc.—*R. E. Thompson* (*Courtesy Chem. Abst.*).

Pymatuning Earth Dam Near Jamestown, Pa. Eng. News-Rec., **107**: 713, October 29, 1931. Unit prices given from contact for Pymatuning dam across Shenango River, together with average unit prices of all bidders (30). Dam, which will be 2400 feet long and 50 feet high, will contain 370,000 cubic yards of embankment and will require 189,000 cubic yards of excavation. Contract was awarded for $339,567.—*R. E. Thompson.*

Albany Abandons Hudson River for Upland Water Supply. Eng. News-Rec., **107**: 531–4, October 1, 1931. Increasing pollution, possibility of floods, unsatisfactory pressure conditions, and demand approaching plant capacity led to abandonment of Hudson River as source of Albany's water supply. Construction on Hannacrois-Basic-Catskill project, the new source, is planned in three stages. First stage, now nearly completed, includes Alcove storage dam on Hannacrois Creek, diversion dam and basin on Basic Creek, 2800 feet of 5 × 6-foot concrete-lined tunnel connecting these water-sheds, 20 miles of 48-inch cast iron conduit, filter plant, and 100-million gallon distribution reservoir in northeastern section of city. Dependable yield is 30 m.g.d. Construction cost was $9,000,000, or $300,000 per m.g.d. of dependable yield. Estimated costs for stages 2 and 3 are $342,000 and $186,000 per m.g.d. Dam consists of earth embankment with concrete corewall, 2177 feet in length and 81 feet (at maximum) high above streambed. Impounding capacity is 12 billion gallons. Diversion dam on Basic Creek is of similar type. Total length, including 100-foot spillway, is 872 feet and maximum height 25 feet. The 670-million-gallon reservoir formed will normally be empty, storage beginning only when 300-second-foot capacity of diversion tunnel is reached. Filter plant, located at South Bethlehem, midway between Alcove dam and city, consists of aërators, mixing basins, coagulation basins, eight 4-m.g.d. rapid sand filters, chlorination equipment, and clear well. Filtration was not

thought necessary, but was required by State Water Power and Control Commission. Natural depressions provided excellent site for distribution reservoir, which consists of 2 concrete-lined basins holding 75 and 25 million gallons, respectively, separated by concrete-lined earth dike. Owing to leakage through joints of side slopes, 1½-inch layer of gunite was applied over entire reservoir surface. Brief cost data are included.—*R. E. Thompson.*

High Efficiency Attained on Albany Pipe Construction. Eng. News-Rec., 107: 534–5, October 1, 1931. Description of construction of 48-inch cast iron pipe line in connection with new water supply of Albany (cf. previous abstract). Although considerable portion was laid in rough, rocky country, machine excavation was employed throughout. Joints were made with leadite. Specifications allowed leakage not exceeding 300 gallons per inch diameter per mile per day under head 50 feet in excess of maximum working pressure. For final tests, entire line was divided into 2 sections at filter plant. One of these, with length of 8.127 miles, showed loss of 89 gallons, the other, 6.252 miles long, only 16.5 gallons per inch diameter per mile per day.—*R. E. Thompson.*

Heavy Construction Program Follows Formation of South Essex Sanitary District. BAYARD F. SNOW. Eng. News-Rec., 107: 731–5, November 5, 1931. Scale formed by neutralization of caustic lime in industrial waste by carbon dioxide from organic wastes, together with deposits of organic matter, reduced capacity of 30-inch outfall sewer to that of 18-inch pipe during 20 years' operation, necessitating use of relief gates at different points in system, which resulted in watercourse pollution. Improvement program included 24-inch pipe line across Porter River, 620 feet long, 30-inch line across Bass River, 800 feet long, 30-inch discharge main across Beverly Harbor, a distance of 2,534 feet, and main 54-inch outfall from Salem Neck extending 8,810 feet from shore. Construction of these submerged cast iron lines is outlined. Plants have been installed for carbonating wastes containing caustic lime in settling tanks, before admission to system. Specially designed Venturi tubes, with split section downstream from throat, to permit examination and cleaning, are employed for flow measurement.—*R. E. Thompson.*

Welded Siphons in New Orleans Drainage System. Eng. News-Rec., 107: 735–6, November 5, 1931. New Lennox Pumping Station of New Orleans Sewage and Water Board includes 4 welded steel siphons, two each of 14 feet and of 10 feet in diameter. Those of former diameter are said to be largest ever built. Boiler plate (¾-inch) used totaled 200 tons, and construction involved 23,950 feet of electric welding.—*R. E. Thompson.*

NEW BOOKS

Selected Papers, Proceedings of the Eighth Annual Conference on Water Purification, October 19–21, 1933. Technical Bulletin 6. West Virginia University, Morgantown, West Virginia. 91 pp. **A Quarter Century of Progress in the Purfication of Acid Waters.** E. C. TRAX. 5–19. Rivers of bituminous coal fields of West Virginia have been acid at some seasons of the year since

1890 and acidity has increased, until now so high, in some streams, that it is impossible to purify satisfactorily even with the most modern plants. Efforts to dispose of mine wastes by discharge into wells has proven unsatisfactory. The sealing off of old workings keeps sulphur-bearing substances submerged and eliminates much acidity. The pondage of mine water and its release during flood seasons has been considered as a remedial measure. Such waters can be neutralized at water treatment plants by lime and soda ash, usually removing all acidity and producing an alkalinity of 3 to 6 p.p.m. to phenolphthalein. Installation of water treatment plants correcting acidity has resulted in greatly reduced rates due to water-borne diseases since people were driven to unsafe sources of water through dissatisfaction with the highly acid water. Bibliography. **The Human Factor in Water Purification.** E. S. TISDALE. 20–27. The quality of water purification plant operating personnel in West Virginia has been improved by supervision of State Health Department, by conferences on water purification, by placement and support of trained men in important posts, and by examination and certification of operators. **The Treatment of Elk River for Water Supply.** P. H. MCLAUGHLIN. 28–35. West Virginia Water Service Company operates three plants on Elk River. At Sutton, chlorination only is used; at Gassaway, six miles below, ammoniation, chlorination, coagulation, and sedimentation; and at Charleston, 90 miles below Sutton and at mouth of Elk River, preammoniation, prechlorination, coagulation, sedimentation, and filtration, with, at times, copper sulphate treatment of river, are employed. **Use of Activated Carbon without Filtration.** F. E. STUART. 36–41. At Belmont Lake, Pennsylvania, 3½ p.p.m. of carbon, applied as slurry from rowboat, was successful in removal of tastes and odors. A 24-hour period for settling was required. At Cambridge, England, 5 p.p.m. of carbon, applied to surface of lake, with outboard motor, was sufficient to remove objectionable tastes and odors. A 48-hour period of settling was required. At Abilene, Texas, carbon was used in continuous water softening plant, without filters, dosage of 2 p.p.m. improving the settling and stabilizing sludge. At Daytona Beach water softening plant (fill-and-draw type), dosage of 2 p.p.m. removed last traces of H_2S odor and improved settling rate of softened water. **Taste and Odor Control with Activated Carbon.** HENRY WIESNER, JR. 42–43. Experience at Weston, West Virginia, disclosed that application of carbon at rate of 3 to 4 p.p.m. to filter effluent removed algal tastes, when 10 p.p.m., applied to raw water with lime and alum, failed. **Demanganization by Prechlorination.** M. J. DAVIS. 44–48. Wellsburg, West Virginia, iron removal and softening plant could not remove manganese by ordinary aëration and sedimentation processes. Chlorination of aërated water followed by settling and filtration completely removed manganese. **Troubles Encountered in the Operation of Small Water Systems.** W. E. HOLY. 49–51. Inadequacy of plant design, service meters, changes of street grades necessitating lowering of mains, and unsatisfactory qualities of water are chief concern of small plant operators. **A Study of Total Solids, Manganese and Acidity and Their Courses Downstream on the North Branch of the Potomac River.** J. G. PATRICK. 52–65. Graphic and tabular data show relative amounts of impurities contributed by each branch of the river and in resultant mixture. **Consumers' Good Will.** T. A. STOUT. 66–69.

Suggestions of means by which public interest in, and sympathetic consideration for, water supply may be promoted. **Effects of Road Oils and Tars on Public Water Supplies.** L. V. CARPENTER and E. W. KLINGER. 70–79. Tests of effect of road oils on stream pollution indicate that washings from roads are apt to cause tastes and odors in surface waters if heavy rain occurs within four hours of application of primer coat. **Enrollment of Eighth Annual Conference.**—*R. L. McNamee.*

Proceedings of the Fifteenth Texas Water Works Short School, Temple, Texas, January 16–18, 1933. 162 pp. **Bacteria and Sanitary Criteria for Water, Evaluation.** S. C. BOHLS. 12–20. Bacterial analysis of water must be interpreted in light of good sanitary survey. U. S. Public Health Service standards are now generally followed for municipal supplies, although they officially apply only to water for use on interstate carriers. Certain spores behave much like *B. coli* and care is needed in differentiation. **Discussion.** O. B. WILLIAMS. Citrate test is valuable in differentiating between fecal and nonfecal strains of lactose-fermenting bacteria. E. G. UMBENHAUER. Instances of lactose-fermenting, spore-forming rod which does not produce gas in brilliant green bile are noted. **Report of Committee on Stream Pollution.** 20–21. **Report of Committee on Water Certification.** 21–25. Recommends application of U. S. Public Health Service standard in modified form to all public supplies. **Jar Test for Coagulation. Control of Chemical Balance of Softened Water.** L. C. BILLINGS. 25–28. Purposes, equipment, and procedure in jar test for water treatment plant operation described. **A New Method of Sewage Disposal by Coagulation, Sedimentation, and Oxidation.** C. C. HAYS. 28–33. **Sewage Irrigation.** D. T. MAULDIN. 33–35. **Required Capacities of Separate Digestion Tanks for an Activated Sludge Tank.** W. S. STANLEY. 35–38. **The Use of Activated Carbon in Connection with Odor Reduction at Sewage Plants.** V. M. EHLERS. 38–40. **Making Full Use of Theoretical Considerations in Water and Sewage Clarification.** H. E. SCHLENZ. 41–51. Consideration of velocity, depth, detention, and distance of flow are important in design of sedimentation tank. [References given to investigation of these factors, but bibliography is omitted.—ABSTR.] **Coagulation with Ferric Chloride in Sewage Treatment.** H. O. BANKS. 52–57. **Diffuser Mediums for the Activated Sludge Process.** F. E. ROE. 57–60. **Public Water Supplies in Texas and Well Protection.** F. A. SCHRAMM. 61–65. Instances of unsatisfactory well water supplies are traced to faulty well construction. **Report of Standards Committee.** 65–66. Relates of licensing of water works operators. **The Knowledge of Activated Carbon in Treating Drinking Water Supplies.** H. R. ARRANT. 66–70. Activated carbon is valuable for taste and odor removal, color removal, coagulation, sludge stabilization, and removal of toxins. **Modern City Practice in House and Service Connections.** A. R. DAVIS. 71–76. Austin, Texas, uses corporation cocks, lead or copper goose necks, copper service pipes, cut-off and meter in meter box just inside curb line, and consumer cut-off. Good engineering records of installation, materials, and locations are found valuable. **Discussion.** J. L. HORNER. Questionnaire shows most Texas cities require permits for construction of service connections. Of 38 reporting, 21 furnish all meters, 11 some sizes, 6 require property owners to

furnish. Of 39 reporting, 15 furnish service and stop cock, 24 require property owners to furnish. Where cities operate plants, meters are generally located in street; where privately operated, on consumer's property. Most cities lay services to curb before paving. **Water Supply Protection.** J. W. BERETTA. 77–81. Planning of public water supplies calls upon abilities in many fields of scientific knowledge. **Modern Features of Well Construction and New Installations.** R. A. TAYLOR. 81–87. Construction of satisfactory wells must be founded on knowledge of underground strata. Variety of types of wells in Texas are discussed. **The Water Supply of Texas A. and M. College.** F. E. GIESECKE. 87–92. Five possible sources for water supply were studied and abandoned in favor of deep wells. **Discussion.** Water from deep wells carried 20 p.p.m. H_2S and 1700 p.p.m. dissolved solids. Treatment included separate aëration in inclosed tower, filtration through activated carbon, and chlorination. **Reservoir Construction and Maintanance.** A. H. WOOD. 92–96. El Paso's water distribution system operates on three zones; low level, with three reservoirs of 60-m.g. total capacity; east high level, with two reservoirs of 7.7-m.g.; and west high level, with one 2.3-m.g. reservoir. Description of newer reservoirs, with construction and cost details recorded. **Report of Committee on Operation and Rating Standards of Public Water Supplies.** 96–106. Recommends numerical rating of public water supplies; suggests rules governing licensing of water plant personnel; favors approved signs at municipal limits. **Report of Committee on Rural Water Supplies.** 107–109. Sources of pollution and types of well protection required are discussed. **Algae Control in Impounding Reservoirs.** CHESTER COHEN. 109–111. Microscopic examination of surface waters will disclose presence of algae before troublesome tastes and odors result. **Factors Affecting Corrosion of Water and Service Mains.** D. W. ROBISON. 111–113. Internal corrosion may be prevented by special pipe coatings and by removal of corrosive elements in water; external corrosion, only by coatings. **Underground Water Studies in Texas.** W. N. WHITE. 113–114. Progress report of investigation of groundwater resources of Texas, begun in 1929 and thus far extended to cover all, or parts, of 25 counties. **A Water Works System in Its Relation to Key Rates.** W. J. MILES. 114–120. A plea for intelligent planning of water works facilities to reduce insurance rates. **The Effects of Politics upon Government.** JOHN N. EDY. 120–123. A thought-provoking discourse; too meaty to be abstracted, too long to be copied. **Report of Resolutions Committee.** 123–124. **Report of Auditing Committee.** 125. **List of Texas Water Works Superintendents.** 125–133. **Tabulation of Texas Municipalities with Water Plants, Sewer Systems, Tourist Camps, Swimming Pools, and Other Sanitary Facilities.** 134–162.—*R. L. McNamee.*

Acid Mine Drainage from Bituminous Coal Mines. LOUIS V. CARPENTER, and L. K. HERNDON. Research Bulletin 10, Engineering Experiment Station, West Virginia University, Morgantown, West Virginia, September, 1933. Drainage from bituminous coal mines in northern West Virginia varies from 500 to 1000 gallons per day per acre of coal exhausted. Drainage water is usually very acid but acidity bears no relation to sulphur content. Buffering action is noticed at pH of 3.0. Drainage will be alkaline if old workings are

sealed from the air. Chemical neutralization of acid mine water is uneconomical, as volume of sludge is too large and cost of chemicals, prohibitive. There are no saleable by-products. Part of sulphate in acid mine water can be attributed to bacteriological action. Acid mine water reduces B.O.D. of sewage polluted streams, but these effects are offset by other harmful results. —*R. L. McNamee.*

Journal of the Pennsylvania Water Works Operators' Association, Volume V, 1933. Papers presented at Sixth Annual Meeting at State College, Pa., September 8–9, 1933. **The Contamination of Open Reservoirs and Tanks by Birds.** R. B. ADAMS. 12–13. Origin of *B. coli* and *B. aërogenes* in a distribution system was traced to open tanks and reservoirs, and final evidence pointed to birds as source of contamination. Bird washings and droppings were studied separately, and *B. coli* and *B. aërogenes* derived there from were culturally identical with those from reservoirs and distribution system. Fecal organism was gram-negative, non-spore-forming, lactose-fermenting bacillus, growing typically as *B. coli* on E. M. B. agar. It was VOGES-PROSKAUER negative and methyl-red positive, produced indol, and fermented saccharose with acid and gas production. (*Courtesy Chem. Abst.*) **Plant Operation at the Danville State Hospital.** S. C. BAILEY. 13–15. Overcoming troubles from mudballs, from short-circuiting in sedimentation basin, and from open reservoir. **Springdale Filter Plant Problems.** M. D. BAKER. 15–16. Coping with coagulation difficulties due to acid water. **Leakage Survey.** JAMES FERGUS. 17. Water flowing into section under examination of distribution system is measured during time of low flow by metered by-pass around main-line valve. No special equipment is needed. **Taste Removal by Pre-Chlorination.** R. W. HAYWOOD, Jr. 18–19. Lehigh Water Company's experiences. **Safe Harbor Water Filtration Plant.** P. M. HESS. 19–23. Small plant successfully creating variable water of Susquehanna River. Illustrated. **The Use of pH in Handling a Complaint.** GORDON JENKINS. 23–24. Systematic pH determination showed that corrosion in automatic pan-washing machine in bakery was due to decrease in pH of washing solution during operation of machine, and not to pH of water used. Change in operation methods so as to maintain constant pH of 8.4 corrected the trouble. **Economic Change in a Pumping Station.** TED H. KAIN. 25–26. Columbia Water Company effects considerable saving by change from steam to Diesel drive. **Lactose Broth Fermenters.** CHAS. R. KEATLEY. 26–27. Neither pre-chlorination, nor pre- or post- treatment with chloramines eliminated organisms fermenting lactose after 24 hours incubation. Brilliant green bile medium has eliminated these false presumptive tests. (*Courtesy Chem. Abst.*) **Changes in Un-iced Bacterial Samples During Shipment.** GILBERT L. KELSO. 27–29. Water samples for bacteriological analysis were exchanged by three laboratories, samples being shipped parcel post un-iced. Under these conditions plate counts were rendered unreliable. *B. coli* tests were reliable 50 percent of the time, while treated samples checked 90 percent of the time. Maximum shipping time was 48 hours. (*Courtesy Chem. Abst.*) **Lime Treatment at Greensburg, Pa.** OSCAR A. NEWQUIST. 29–31. Corrosiveness checked. Point of application of lime is important. **Reconditioning Filters.** MAX U. PRIESTER. 31–33.

From 15 to 20 pounds of chloride of lime was added to each filter unit and the solution drawn into the sand. After 48 hours contact, filters were washed and allowed to dry 24 hours. They were then backwashed while being agitated by 1-inch stream from high-pressure line. The 1-inch pipe, 8 feet long, was worked up and down through the sand by two men. Filter operation was noticeably improved by this treatment, deposits of iron, manganese, and organic matter being removed from sand. In **discussion** of foregoing papers, JAMES M. CAIRD instanced successful protection of open reservoirs from gulls by fine copper wires strung across at 20-foot centres, both ways and at height of 2 feet above ground, from posts 3 feet back of water's edge. **Algae.** GEO. R. TAYLOR. 34–40. Thorough, detailed, and elementary discussion of examination, enumeration, and significance of algae in water supplies. List of equipment needed, with estimated cost, is included. (*Courtesy Chem. Abst.*) **Road Oils and Tars and Their Effects on Water Supplies.** MARTIN E. FLENTJE. 41–42. In one instance, chlorinated water in distribution reservoir developed taste after adjacent highway had been freshly surfaced. Either phenol or petroleum products used in surfacing material may be potential cause of tastes and odors. (*Courtesy Chem. Abst.*) **Effects of Road Oils and Tars on Public Water Supplies.** LEWIS V. CARPENTER and EARL W. KLINGER. 43–46. Small test sections of road were prepared according to specifications of W. Va. State Road Commission and washed with distilled water equal in quantity to one inch of rainfall. Washings were collected and tested as follows for taste and odor. Samples of 500 ml. were distilled and 300 ml. of distillate collected. Distillate was made up to 500 ml. and dilutions of 1:20, 1:200, 1:2000, 1:200,000 prepared. These dilutions were chlorinated to a residual of 0.3 p.p.m., free chlorine removed, and warm odor and cold taste determinations made according to Standard Methods of Water Analysis 1933. Results indicated that when roads were surfaced with a "primer" coat, there was distinct danger of chlorophenol tastes in water supplies if heavy rains occurred within two hours after application. Danger is not so pronounced from "retread" material. (*Courtesy Chem. Abst.*) **The Service of the Laboratory to the Water Purification Plant.** HARRY E. JORDAN. 47–55. Laboratory and its staff fill their proper place in modern purification plant only when they impinge upon and affect daily routine of entire purification process. Laboratory staff must dominate plant operation. Twenty percent of typhoid and 50 percent of dysentery charged against water supplies during period 1920–1930 was due, not to absence of, but to failure of, purification process. Sudden outbursts of obscure intestinal disorders deserve more attention than they have received. Limitations of purification processes must not be forgotten. Importance of regularly conducted plant control tests is stressed. Unreliability, under certain conditions, of *ortho*-tolidine test is mentioned. Modified procedure for determination of phenols is included. (*Courtesy Chem. Abst.*) **Coagulation.** MARSDEN C. SMITH. 56–63. Prechlorination is sometimes an aid to coagulation, and saving in coagulant may exceed cost of chlorine. Reduction of industrial waste present in raw water, installation of flocculators, and laboratory check on coagulant dosages with stirring machine resulted in following savings: Coagulant, 50 percent; wash water, 83 percent; and carbon, from 75 to 100 percent. No constant optimum pH was found. Best taste and odor control was

obtained by adding entire carbon dose to top of filter at beginning of run: method for accomplishing this is described. Procedure for colorimetric determination of aluminum in filtered water is included. (*Courtesy Chem. Abst.*) **Filter Operating Experiences.** L. E. WICKERSHAM. 64–71. Intelligent operation should produce water of satisfactory quality with minimum of chemicals. Unnecessary tests and records are to be avoided. Too much dependence should not be put on dosage charts prepared for general use, as each water is a problem of itself. Problems arising in supervision of purification in different plants are reported. (*Courtesy Chem. Abst.*) **The Construction and Protection of Drilled Wells.** A. G. FIEDLER. 72–82. "Cable-tool percussion" and "hydraulic rotary" methods of well drilling are discussed. Methods for protection of drilled wells from contamination and for protection of casing are given. Completed well may be chlorinated under pressure, or by introducing strong chloride of lime solutions with dump bailer. (*Courtesy Chem. Abst.*). **Application of Fine Anthracite to Water Purification.** H. G. TURNER and G. S. SCOTT. 83–90. Use of anthracite as filter medium instead of sand is still in experimental stage. Name "anthrafilt" has been given to material specially prepared and conforming to rigid specifications. Eight points of superiority over sand are presented. (1) Anthrafilt is superior for turbidity removal, due to angular shape. (2) Initial loss of head is less. (3) Longer filter runs are obtained. (4) Backwashing velocity is 50 percent less. (5) Bacterial removal is superior. (6) Anthrafilt is practically insoluble in hot alkaline waters. (7) Lime coatings adhere but loosely. Light weight makes it no more expensive than sand and is a structural advantage in some instances. —*G. L. Kelso* (*Courtesy Chem. Abst.*).

Proceedings Seventh Annual Conference—The Maryland-Delaware Water and Sewage Association, 1933. Stream Control in Maryland. F. H. DRYDEN. Following the Act by the General Assembly of Maryland in 1931, the Governor appointed a Water Resources Commission charged with the duty of making a study of the water resources of the State and presenting their recommendations for a program of State supervision to the 1933 assembly. As a result of the report the 1933 Legislature enacted a law declaring it to be the policy of the State of Maryland to control the appropriation or use of surface and underground waters of the State; to control and supervise the construction, reconstruction and repair of dams, reservoirs and all other water-works in any water of the State, and creating the Water Resources Commission and charging them with devising and developing a general water resources conservation program. **Cast Iron Pipe and Fittings for Sewer House Connections.** H. ROLAND DEVILBISS. Since 1918 the Washington Suburban Sanitary District has constructed approximately 160 miles of sewers and 8700 house connections. Their conclusion is that a sewer house connection constructed of cast-iron pipe and fittings from the main sewer to the property line or through to the house with joints of leadite, mineralead, sulphur compound and lead, provide a cheaper service in first cost, at least as durable, if not more so, than can be secured with any other types of pipe commonly used for this purpose, and most certainly a service lower in maintenance cost. **Public Utilities in Small Towns.** L. D. SHANK. The City Manager plan of government in Dover, Delaware,

has made its utilities profitable in addition to providing more dependable service with low rates. The capacity of the electric plant was increased from 400 to 2500 kw. at the same time reducing generating costs from 7 cents per kw., at the board, to 8 mills. The cost of pumping water has been reduced from $1200 to $500 per month in spite of the increase in pumpage from 450,000 gallons to 750,000 gallons per day. The profits of the water works in 1925, with nothing charged for pumping, were about $5,000, but the electric plant lost twice that amount. By the installation of up-to-date pumping and generating equipment and the installation of larger water mains, thereby reducing losses due to friction in small pipes, the city was able to show a profit, in 1932, $12,000 in the water department and $87,818 in the electric department. **Filter Sand and Washing Experiences at Washington, D. C.** C. J. LAUTER. This paper covers the period from January 1928 to April 1933, the conclusions being based upon actual performances of filter beds and on results from small glass filters. When the Dalecarlia filter plant consisting of 204-million-gallon units, was completed in 1927, it was planned to use sand of 0.45 mm. effective size. The McMillan slow sand plant had 29 acres of available sand with an average effective size of 0.30 mm. and a uniformity coefficient of 1.25 to 1.4. This meant that at least 40 percent must be discarded to get the 0.45 mm. size, but even this loss did not exceed the difference in cost of the two sands in question. The plant was filled with 24 inches of the McMillan sand allowing for 6 inches of the sand to wash out and thereby increase the effective size. However due to design it was impossible to wash this all out without danger of blowing up a bed. Hard spots and cracks developed and in July 1930 air and water jets of various designs were tried and abandoned. Finally a 2-inch fire hose was used, playing a sharp stream from a $\frac{3}{4}$-inch nozzle at 50 pounds pressure, on the drained filter over the sand surface, being careful not to hold it too long in one spot. This operation has been successful in preventing cracks and ridges and has kept the beds in a very satisfactory and level condition. **Cellar and Open Area Connections to Sanitary Sewers.** ELLWOOD JOHNSON. To overcome the problem of overcharging of sanitary sewers by illegal areaway drains it is suggested that all premises abutted by sanitary sewers be periodically inspected, with strict enforcement of the plumbing code. **The Baltimore Garbage Incinerator.** O. H. SCHROEDL. This paper discusses the design of the new 600 ton incinerator and the features of the ten year contract at the expiration of which the incinerator automatically becomes city property. Based upon quantities of materials collected in 1932 and compared with the unit prices paid in that year, the new contract will save the city approximately $324,000 annually. **Meeting Our Responsibilities.** HARRY E. JORDAN Water supply and Sanitary District men are called upon to defend themselves not only against unreasoning reductions in funds for sanitation but also by their attitude toward their duties, to counteract the tendency of the mass-mind to minimize the importance of well trained organizations in public service. Water supply is related to community and individual life in four ways: it is the first bulwark of fire protection; it is related to sanitation as it affects sewage removal; it is related to bodily well being as it contributes to metabolism, and it is related to good health by the good quality that it has. The following phases of operation are discussed as hav-

ing a bearing upon the value and character of service that the water supply organization renders to the community: (1) the policy and method of organization of the department; (2) plant facilities; (3) quality of the supply; (4) services to the consumers, and (5) the attitude of the community towards its own public affairs. The author discusses the following seven things which should be foremost in the minds of the water plant operator: (1) be master of your plant; (2) standardize repeated operations; (3) emphasize the vital importance of preparing water for filtration; (4) put your finger upon the most significant variable in your plant operation; (5) one major step in plant operation is the training of every invidual in chlorination control; (6) the laboratory work on any water purification plant outside of the control activities, has its major value as a historical record on the performance which you have produced, and (7) be known in your community and not only known but be respected. (Abstractors note; This paper merits careful reading by every water plant operator.) **Forest Planting for Watershed Protection.** F. W. BESLEY. The influence of a forest cover in regulating the run-off and conserving water supplies is discussed. The forest litter and humus not only absorb and hold the rainfall but furnish a protective covering which keeps the underlying soil in a porous condition ready to store water and prevents, to the highest degree, soil erosion and the consequent silting of reservoirs. The forest cover is permanent and the easiest and cheapest to maintain of any cover protection. It reduces evaporation, and may produce a timber crop of high value which may be harvested without reducing the protective value of the forest. **Sewage Disposal Plant at Wilmington, Delaware.** HARRY L. MAIER. A description of the sewage treatment plant which was completed in March 1932 at cost of $81,450, including land and laboratory. Plant consist of grit chamber, 3 primary tanks, 2 dosing tanks, 2 Adams type sprinkling filters, 1 final tank, 2 sludge tanks and a sludge bed. **The Latest Development in Automatic Water Pumping Stations.** LEON SMALL. In the operation of automatic pumping stations the status of the station is always a matter of some concern to the officials responsible for the continuity of the water supply, in spite of precautions against breakdown that have been taken through the installation of devices intended to protect against the results of mechanical or electrical failures. In order to overcome this, Baltimore City installed a telephone supervisory system in two of its pumping stations. This system appears to be entirely satisfactory. By its use, complete information concerning the essential features of the stations is available at all times, through the medium of an ordinary telephone call from any part of the public telephone system, plus a knowledge of the simple code in which the supervisory apparatus responds to the call. Any doubt concerning the operating fitness of either of the stations can be settled almost immediately if conditions are not right, the nature of the trouble is indicated and in this way valuable time is gained, as the trouble-shooter knows generally what is required to restore the station to service without the necessity of a visit to it to learn what is wrong.—*A. W. Blohm.*